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PRESENT-DAY SHIPBUILDING.

A MANUAL FOR STUDENTS AND SHIPS' OFFICERS FOR THEIR RESPECTIVE EXAMINATIONS; SHIP-SUPERINTENDENTS, SURVEYORS, ENGINEERS, SHIPOWNERS, AND SHIPBUILDERS.

Being Chapters III., IV., VI., VII. of "Steel Ships," revised, enlarged, and specially arranged, with Test Questions and Answers.

BY

THOMAS WALTON,

NAVAL ARCHITECT,

AUTHOR OF "KNOW YOUR OWN SHIP," "STEEL SHIPS: THEIR CONSTRUCTION AND MAINTENANCE."

Illustrated with Plates, Folding Diagrams reduced from Working Drawings, and Illustrations in the Text.

LONDON:
CHARLES GRIFFIN & COMPANY, LIMITED.
PHILADELPHIA: J. B. LIPPINCOTT COMPANY.
1907.

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PREFACE.

WHILE externally the general appearance of the hulls of merchant steamers has not presented any very striking change in recent years (with the exception of turret and trunk steamers), yet, internally, decided improvements and numerous modifications have been made in ship construction. Instead of the old-fashioned practice of obstructing the hold-spaces with tiers of beams, hosts of pillars, wide and cumbersome side stringers, etc., ingenuity of late years has discovered the means of getting rid of much of this hold obstruction, and frequently a tier of beams is dispensed with, and in some cases hold pillars have entirely disappeared, while, generally, they have been greatly reduced in number. Very compact and snug side stringers in holds have become the prevailing practice, while in some large vessels built recently, even side stringers have vanished entirely, by the manipulation of deep framing in conjunction with extra strength in other parts of the structure.

The hold-spaces of modern cargo steamers are consequently very much better adapted for the stowage of cargo. Such advantages the shipowner can well appreciate.

Efficient ballasting has also been effected in many vessels by economical modification in the usual mode of construction. The benefit of this is best realised by ships' officers and seamen,—and underwriters.

On deck, large broad hatches, short masts and absence of sail, or, numerous twin derrick masts with elaborate gear for the rapid loading and discharging of cargo, are all prominent features in many modern cargo vessels.

The necessity, therefore, for a compact practical treatise upon present-day ship construction, containing complete illustrations of the latest types and practice in shipbuilding, arranged to meet the requirements of students for naval architecture examinations, ships' officers for their examinations for masters' certificates, ship surveyors and superintendents, draughtsmen, engineers, shipowners, etc., and issued at a price that will bring it within the reach of shipyard students and others who are not able to procure the more elaborate and costly works upon naval architecture, is the explanation given for the issue of this volume of moderate proportions, which in reality is one section of the author's larger and more expensive work, *Steel Ships: their Construction and Maintenance*, extended by much new matter and many fresh illustrations to meet this want.

In response to several suggestions, a number of questions upon practical ship construction, with brief answers, are given at the end of the book, for the guidance and assistance of students not practised in answering examination tests.

The Author desires to express his thanks to the Cunard Steamship Co., Liverpool, for permission to publish the information given in connection with their new turbine-propelled, quadruple-screw express steamers, the "Lusitania" and "Mauretania," and to Mr A. G. Hood, Editor of *The Shipbuilder*, for the use of the blocks, for the valuable launching illustrations, etc., of the "Mauretania"; and also to the following shipbuilders:—Messrs Armstrong, Whitworth & Co., Ltd., Wm. Doxford & Sons, Ltd., Ropner & Son, J. Priestman & Co., Sir Raylton Dixon & Co., Ltd., Short Bros., Ltd., S. P. Austin & Son, Ltd., for permission to illustrate particular vessels built by them, and some details of their methods of construction.

THOMAS WALTON.

SUNDERLAND, *October* 1907.

CONTENTS.

CHAPTER I.

CLASSIFICATION.

CHAPTER II.

OUTLINE OF PRINCIPAL FEATURES AND ALTERNATIVE MODES OF SHIP CONSTRUCTION.

CHAPTER III.

TYPES OF VESSELS—SECTION I.

SECTION II.

CHAPTER IV.

Details of Construction.

PLATES AND ILLUSTRATIONS.

PRESENT-DAY SHIPBUILDING.

CHAPTER I.

CLASSIFICATION.

Purpose for which Classification Societies exist—Societies empowered to assign Load Lines—Government the Supreme Authority for Assignment of Load Lines and responsible for Seagoing Condition of Vessels leaving British Ports—Standard of Strength upon which Load Lines are assigned—Load Lines of Three Deck, Spar Deck, and Awning Deck Vessels—Grades of Class—Maintenance of Class—Unclassed Vessels.

Purpose for which Classification Societies exist.—A1 at Lloyd's is a phrase more often used than fully understood, though every seaman knows that it conveys an idea of the good quality and seaworthiness of a ship.

Such an expression brings us into contact with a subject of paramount importance, viz., "Classification," and as a large proportion of seagoing vessels are "classed," and the structural strength in new vessels and the manner in which such structural strength has been maintained in old vessels determines the "class" to which they belong, it will be well at the outset to obtain a clear idea of this matter of "classification."

A steel or iron ship is often compared, from the point of view of strength, to a beam or girder, and in many respects such a comparison may fairly be made. When iron or steel girders are used in the construction of bridges, buildings, etc., a very close approximation can be made to the nature and amount of the severest stresses which may have to be borne; and thus the necessary strengths and dimensions of these girders can be arrived at almost entirely by calculation, provided that the quality of the material is thoroughly understood. But when we come to the actual ship girder, we find ourselves confronted by considerable difficulties and complications, which make the determination of the scantlings and disposition of the material in order to ensure sufficient strength, a matter which cannot be ascertained purely by calculation. The innumerable varying and sudden stresses which are experienced by ships in a seaway, when rolling and pitching in light, loaded, or ballast conditions, render absolutely *accurate* mathematical treatment impossible. However, an *approximate* mathematical calculation can be made which is exceedingly useful.

The other factor necessary in arriving at an adequate knowledge of required strength is experience. Thus we find, throughout the history of iron and steel shipbuilding, continual changes have been made in the generally accepted rules, as experience has indicated their necessity.

All ships are built to carry. Some, as in the case of steam yachts, though two or three hundred feet in length, have little else to bear than the owner, his family, a few guests, the crew, bunker coal, stores, and provisions. Other vessels, such as tramp steamers, are built to carry cargoes of great specific gravity. The former are so light that, in order to sufficiently immerse them, considerable quantities of permanent ballast are usually carried. In the latter, on the other hand, if the holds were entirely filled with cargo of the nature referred to, the vessels would be almost, if not entirely, immersed, and apart from considerations of strength —assuming them to be able to float—the question of stability, with little or no freeboard, would probably be a serious matter.

The purposes for which ships are built are innumerable, and to build all vessels which are similar in size and proportion, of equal structural strength, regardless of the work they have to do, would be absurd. What is more reasonable and sensible is to ensure that each vessel is sufficiently strong to satisfactorily perform her own work. To introduce as much structural strength into a cross-channel passenger steamer which has to carry little else than passengers, mails, and luggage, besides her own equipment, stores, and bunkers, as into a vessel of equal dimensions which has to carry, say, 1000 or 1500 tons of cargo to any part of the world, would be foolish in the extreme. Or even in the case of two purely cargo-carrying vessels of identical dimensions, if one is intended to be solely employed in carrying a cargo of great density, such as coal, while the other is intended to carry a cargo of much less density, such as wool, the one amounting to, say, 3000 tons, and the other to only about 2000 tons, obviously it would be absurd to build each of these vessels to exactly the same scantlings, for either the one would be excessively strong, or the other dangerously weak. But, as stated, it is necessary that each vessel should be strong enough to do her own work.

The strength of ships, therefore, should be regulated by their proportions and maximum displacements, provided that enough freeboard remains to ensure sufficient stability and a condition of general seaworthiness.

It is clear that to study and tabulate the scantlings for every new ship lies outside the sphere of the shipowner. That shipbuilders, by their wide experience, would be vastly more capable of adequately dealing with the matter, is true; but then, without a fixed standard of strength, no two of them would either arrange their material alike, or arrive at the same strength in the finished vessel, even for similar vessels under similar conditions. Moreover, no such method of ship construction would be either satisfactory or acceptable to underwriters. From both owners' and underwriters' standpoint, standards of strength, both for maximum displacements and minimum freeboard, are absolutely essential. Or in other words, a guarantee is required that the vessel is strong enough to carry with safety, and without injury to herself when experiencing the various and probable demands which may be made upon her strength, a certain load, which may not, under any conditions, be exceeded, and also that her design is such that, with a minimum reserve buoyancy when properly loaded, she runs no risk of capsizing through deficient stability. With this aim in view, there exist several societies which, by scientific and mathematical investigation coupled with long experience, have drawn up rules and tables of scantlings suited to all types of cargo and passenger vessels. The best known of these societies are Lloyd's Register, the British Corporation, the Bureau Veritas, the Germanischer Lloyd, and the Norske Veritas. These societies save both shipowners and shipbuilders an immense amount of labour and trouble, at the same time providing general uniformity in strength, and a satisfactory guarantee of efficiency to the insurance societies for the vessels constructed under their rules. To carry out this system, the committees of these societies employ considerable numbers of surveyors, whose training and experience have specially fitted them for the work. The quality of the material used in the construction, the efficiency of the workmanship, the carrying out of their societies' rules and requirements, and the periodical survey for the renewal or alteration of the "class" of the vessels placed in their hands, are their sole responsibility.

The Load Line Act of 1890.—Before the Load Line Act came into force in the year 1890, the overloading of ships, which was a source of danger from both a structural and stability aspect, was attended with loss of life at sea as well as loss of ships. The necessity for Government interference so impressed itself upon this country, that the passing of the Load Line Act was the final result, by which the Government became supremely responsible for the seagoing condition of all British vessels and vessels leaving British ports.

Societies empowered to assign Load Lines.—Hence, while the British Government has sanctioned Lloyd's Register, the British Corporation, and Bureau Veritas Classification Societies to assign load lines to vessels classed by them, the Board of Trade still remains the supreme authority for such assignment. It is certainly true that these societies can build ships to whatever scantlings they please, but it is the work of the Board of Trade to ensure that a maximum load line be fixed strictly in accordance with the strength of such vessels, with a reasonable percentage of reserve buoyancy.

Standard of Strength upon which Load Lines are assigned.—While considerable latitude is thus allowed in the disposal of material in the ship structure, the necessity for a *minimum* standard of strength is obvious. This is, moreover, essential in order that uniformity in the strength of the different types of vessels built be secured, while it does not necessarily follow that uniformity in the modes of construction will be a result. *The* *standard of strength laid down for the guidance of all classification societies is that embodied by Lloyd's Rules for the year 1885.* This gives the minimum structural strength for a minimum freeboard for all classes of vessels. Any society is at liberty to demand greater structural strength in vessels classed by them than that of the Board of Trade standard, and, naturally, they are individually responsible for efficient local strengthening.

Societies for the classification of vessels are thus at liberty to arrange and formulate their own methods of construction, and determine the scantlings of the material used in ships built to their particular classes. With uniformity of strength, uniformity in assigning the freeboard of every class of vessel is secured, since it must be in accordance with the Freeboard Act of 1890.

To the shipowner this subject of classification is of the greatest importance. If he wishes to add a new vessel to his fleet, and he is desirous of ensuring her being built to the highest class, he inserts a clause in his specification, or in the contract between himself and the builders, to the effect that she must be classed 100 A1 at Lloyd's, or to the corresponding highest class in any other society.

Load Line *of "Three Deck," Spar Deck, and Awning Deck Vessels.*—There are four principal types of steel vessels considered in the Board of Trade Freeboard Tables, viz., "Three Deck," Spar Deck, Awning Deck Vessels, and Sailing Ships. A vessel may belong to the highest class in any one of these types. The "three deck" type is the strongest vessel built, and is thus allowed the minimum freeboard, with consequently the maximum immersion, displacement, and carrying power. Awning decked vessels * are the lightest type built for over-sea voyages, and consequently are required to have the greatest freeboard, with consequently smaller immersion, displacement, and carrying power. Supposing that into such an awning decked vessel more structural strength than is required by the standard (Lloyd's Rules for 1885) is introduced, a comparison would be made between her increased strength and that required for a spar decked vessel, and a proportionate reduction made in the freeboard. Or, if a spar decked vessel were built in excess of the standard strength, a comparison would be made between her increased strength and that of a "three deck" vessel, and a proportionate reduction made in her freeboard also. But as the "three deck" vessel has already a minimum reserve buoyancy, additions of strength beyond that required by rule would obtain no concessions in the matter of diminished freeboard.

Grades of Class.—While it is customary for shipowners to have new vessels built to the highest class of their respective types, it does not follow that such vessels will always maintain the highest class; for example, at intervals of four years, Lloyd's require that vessels classed with them should be subject to special surveys. These special surveys are designated No. 1, No. 2, No. 3, and No. 4 respectively, and as long as a vessel maintains her

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* See page 37 *re* Modern Awning Deck Vessels.

structural strength, she maintains her class; but as soon as she begins to deteriorate, and suffer reduction in structural strength, her class may be reduced to 90A or 80A, which simply means that, as she is now less able to carry the same deadweight as originally, her freeboard is increased until her carrying power is in accordance with her strength.

Maintenance of Class.—It is, however, possible, by carrying out certain repairs, to restore the vessel to her original strength and class. "If a vessel is at a port in the United Kingdom after the expiration of the prescribed period for survey, and is not subjected to the special survey then due before leaving the United Kingdom, the word 'Expired' is inserted against her character in the Register book; and in no case will a vessel be allowed to retain her class, if she has not been subjected to the whole of the requirements of the requisite special survey within twelve months from the date when the survey became due." (Lloyd's Rules.)

On the shipowner contracting with the shipbuilder for the building of his vessel to class, say, 100 A1 at Lloyd's, 3/3.1.1. Bureau Veritas, or B. S. of the British Corporation, the first work of the shipbuilder is to have drawn a set of plans upon which is shown the structural arrangement of the vessel in accordance with the instructions contained in the Classification Society's Book of Rules; and the scantlings of each structural part, whether of iron, steel, or wood, are figured upon these plans. They are next sent to the classification society's registry through the local surveyors, where the scantlings are checked, and the special structural requirements of this particular vessel are considered. The plans are then returned to the shipbuilder with the necessary corrections or additions required clearly marked upon them. This is the first introduction the ship has to the classification society, but from that day to the time of her completion she is the object of their constant attention. Indeed, throughout her existence, so long as she is "classed" she is periodically subject to inspection by their surveyors. The steel must also be of the quality required by the particular society, and therefore such instructions accompany the specifications sent to the steel mills where the plates and bars are rolled, and the forgings or castings made. Before these are sent back to the shipbuilder, they must be tested by the classification society's testing surveyors, and the stamp of the society's approval must be upon them. As the work of building the ship proceeds, and the various parts are united, the ship surveyors are ever watching that the steel or iron has the test stamp upon it, that the plates and bars are to the dimensions indicated upon the corrected original plans submitted by the builder, that the connections of plates and angles, and the size and spacing of the rivets, are strictly in accordance with the rules of their society, and that the general workmanship is satisfactory. In this manner, the ship is daily under the eye of these surveyors.

Simultaneously with the building of the ship, the engines and boilers are constructed, and here again the work is under the superintendence of the society's engineer surveyors. Even the thicknesses of the plates and the minimum diameters for steel masts, size of wire for the rigging, weight of anchors and cables, are all determined in the Classification Society's Rules, and the last-mentioned are subjected to their tests. Appliances for life-saving, boats, life-belts, etc., are, however, all regulated by the Board of Trade.

When at last the vessel is completed, and the watertightness of ballast tanks, peak bulkheads, decks, etc., have been tested, and the whole work carried out to the satisfaction of the surveyors, the minimum freeboard for vessels of this class is permanently marked upon the ship's side. The shipowner is then provided with a Certificate of Registry, and the vessel is entered in the Register of the society with which she is classed, and denominated according to her class and type. Thus, by having his vessel classed, not only has a shipowner the satisfaction of knowing that she is well built, but, as she is periodically surveyed, he is further assured as to the maintenance of her strength, while, in the event of his desiring to sell her, her class is a guarantee to the purchaser as to her structural condition.

Moreover, as the vessel will probably be insured when she proceeds to sea, her class is the only guarantee the underwriters have as to her strength and the condition in which she has been maintained.

Note.—Although it is customary for a shipowner who intends having a new ship classed, to have her built to the rules and under the supervision of the surveyors of the society with whom he purposes to have her classed, yet this is by no means an absolute necessity. A vessel may be built independently of all society rules, and still obtain a class. Before any society, however, would grant this, the vessel would require to be thoroughly surveyed by their surveyors, and after an accurate estimate had been made of her structural worth in comparison with their own particular standard, a class corresponding to one of the grades of the classification society in question would be assigned to her, with a maximum load line in accordance.

Unclassed Vessels.—That a ship should be classed with any society in order to receive a load line in accordance with her strength is not essential. Thus, many large shipowners, who employ thoroughly capable naval architects, design their own vessels, and determine the scantlings themselves. When such a vessel is completed and ready for sea, and a load line is required, application is made to the Board of Trade (or to one of the societies empowered to assign load lines), who employ a large staff of ship, engineer, and nautical surveyors, by whom the vessel is thoroughly surveyed, and who fully report upon the workmanship and scantlings; and finally, a freeboard is assigned in accordance with the vessel's strength judged by the standard previously described. Such vessels are distinguished by the term "unclassed," though it should be clearly understood than an unclassed vessel is by no means necessarily inferior in any way to a classed one.

CHAPTER II.

OUTLINE OF PRINCIPAL FEATURES AND ALTERNATIVE MODES OF SHIP CONSTRUCTION.

Transverse and Longitudinal Framing—Form and Function of Parts—Butts in Transverse Framing—Framing in Double Bottoms—Regulations for Increasing the Number of Tiers of Beams—Compensation for Dispensing with Hold Beams, a Steel Deck, Hold Pillars, Side Stringers—Necessity of Thorough Combination of Transverse and Longitudinal Framing—Structural Value of Shell Plating—Alternative Modes of Construction—Numerals for Scantlings.

Possibly the knowledge of ship construction possessed by many readers may be of a very limited character, and in this chapter it is simply proposed to briefly enumerate the principal parts in the structural arrangement of ships, so that the names of such parts may become familiar, and to give a general idea of their functions. This plan, it is believed, will simplify the course pursued in this work, besides curtailing elaboration and explanation in the longest division of the book, dealing exclusively with "Details of Construction."

Framing.

Steel and iron ships are built on a combination of two systems of framing, viz., longitudinal and transverse.

Longitudinal Framing includes all girder forms of material which run in a fore and aft direction, whose function is to afford longitudinal strength.

Transverse Framing embraces all girder forms which cross the longitudinal framework at right angles, affording transverse or athwartship strength.

The strongest structure is obtained only when these two systems of framing have been intelligently woven together, the strength of the one co-operating with the strength of the other—that is, in relation to the work which, conjointly, they have to do. When this is accomplished, the whole is then covered by a skin, in the form of "shell plating" and decks, which not only stiffens and strengthens the skeleton or framework, but adds enormously to the total strength of the ship considered as a compound girder.

Transverse Framing.—In order to preserve the transverse or athwartship form of a ship under all the conditions of stress to which ships are subject in carrying their various loads in smooth and wave water, a girder or frame is placed at intervals of from 20 to 30 or more inches apart, all fore and aft.

Fig. 1 gives an example of the simplest form of transverse framing. Here we have a half section of a comparatively small vessel showing such a transverse frame, with what are known as ordinary floors. It consists of a frame bar, a reverse frame bar, a floor plate, a beam, and a pillar or stanchion. The efficiency of the complete frame depends upon the thoroughness of the combination of the various parts into one whole.

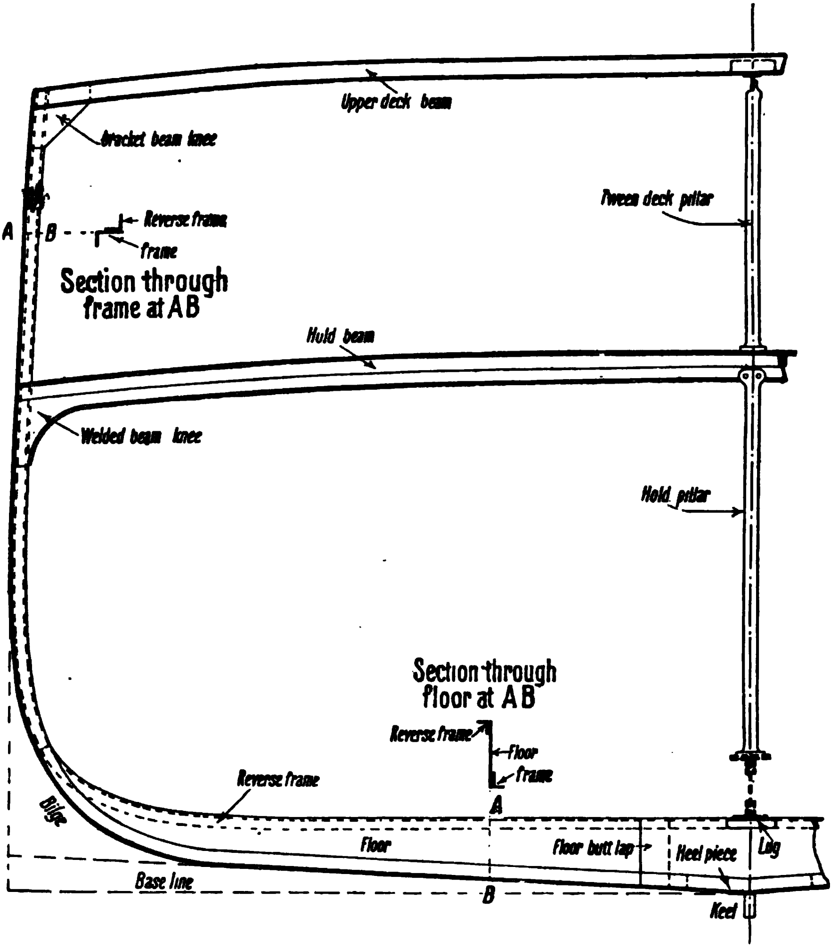

FIG. 1.—Midship Section showing Transverse Framing with Ordinary Floors.

Frames.—The *frame bar,* in this system of framing, is continuous from the top of the keel to the gunwale, extending from the top of the keel to the bilge along the lower edge of the floor plate to which it is riveted.

Reverse Frames.—The *reverse bar* also extends continuously from the middle of the upper edge of the floor plate on the opposite side to the frame (shown by dotted lines on the section) round the bilge, then on to the frame bar to the gunwale, except in the smallest vessels, though the alternate reverse bars do not usually extend to this height.

Floor Plates.—The *floor plate* extends from bilge to bilge, either in one plate, or in two plates butted (joined end to end) alternately on either side of the centre line. The frame and reverse bars are riveted to its lower and upper edges respectively, converting the plate into a girder with top and bottom flanges, which strengthen it to resist athwartship buckling. (See fig. 1.)

The height of the bilge ends of the floor plate above the base line is usually about twice the depth of the floor at the middle line of the ship; and at three-quarters the half-breadth out from the middle line it should be at least half the depth of the floor plate at the middle line.

The advantage of carrying the floor plate round the turn of the bilge must be obvious, strengthening what is liable to be a weak place in the framing, especially in very square-bilged ships. At such a corner, "working" is more liable when the vessel is subject to the severe stresses which are experienced among waves, tending to produce alteration in the transverse form.

Beams.—The beam is a steel or iron bar, uniting (in a single-decked ship) the uppermost extremities of the frame, and preventing, by its own tensile strength and rigidity, the tendency of the frame heads to open wider apart from each other or to approach each other when the vessel is subject to stresses consequent upon loading, or from the pressure of the water upon the immersed skin of the ship. Beams thus perform the function of both struts and ties.

Here, again, much depends upon the efficiency of the means of connection, and also in thoroughly supporting the angular connection of the beam to the frame. Hence it is necessary to form a web of plating (beam-knee) which should extend at least two and a half or three times the depth of the beam down the frame, to which it is securely riveted. We shall refer more fully to this in Chapter IV. Owing to the depth of the vessel illustrated in fig. 1, additional transverse support is required to the sides between the weather deck and the floors. An additional tier of widely spaced beams is thus introduced.

Pillars.—It is scarcely necessary to say that, the shorter a bar is, the more rigidity does it possess, and also, that the fullest efficiency of any structure whose strength is made up of a number of parts can only be fully developed when such parts are combined in the most perfect manner so as to cause the entire combination to act as one piece. Hence, in order to develop the full efficiency of the transverse frame, its several parts must be "tied," in order to prevent their acting independently of one another. Pillars are therefore introduced, uniting the beam at the centre with the floor at the centre. These act both as struts and ties, preserving the distance relationship of these opposite parts of the structure. Moreover, without pillars (or some structural formation equivalent to pillars—see figs. 44 and 52), any severe crushing stress upon the sides of a ship would tend to cause the beam to spring up at the centre, its great length reducing its rigidity and resistance to bending; on the other hand, they are needed to support the numerous and varying loads—both stationary, as winches, windlasses, etc., and temporary, as deck cargoes. Where the beam is very great, additional pillars, termed quarter pillars, are introduced between the centre ones and the sides of the ship, or else a substitute of some kind is required. Before leaving, for the present, the subject of hold pillars, it may be pointed out, as shown upon pages 71 and 72, figs. 44 and 45, and page 79, fig. 52, and Plates 9 and 10, that both hold pillars and a tier of hold beams may be entirely or partially dispensed with by adopting a system of framing which combines in its formation all the structural advantages of hold beams and pillars, and moreover preserves a clearer hold space.

Butts of Frame and Reverse Frame.—Though both the frame and the reverse frame have a break in their lengths at the centre line above the keel, in each case it is intended that the strength of these bars be continuous. To unite these ends by such means as will ensure this is therefore necessary. In the case of the frame, this is done by fitting a *heel piece* (a piece of angle iron about 3 ft. long, of the same size as the frames), on the opposite side of the floor and covering the butt, and in the case of the reverse bar, by fitting a short covering piece on the opposite side of the floor also. (See figs. 1 and 4.) These butt-covering bars also perform other services in the ship structure, as will be shown later.

Transverse Framing in Double Bottoms.—The system of so constructing the bottoms of vessels as to make them capable of carrying water for trimming purposes or as ballast has become more and more universal during recent years.

The earlier forms of these double bottoms were called M'Intyre tanks, after the name of the inventor. At first these tanks were so built that the transverse framing was maintained in the usual way, the inner bottom being formed by laying the plating upon fore and aft girders standing on top of the ordinary floors. In some cases the inner bottom plating extended horizontally out to the ship's side, where it was made watertight by fitting angle collars round the frames. In the most common form of M'Intyre tank, however, the tank side in each wing is formed by turning the inner bottom plating down perpendicularly to the bilge. Here, again, the frame bar was sometimes continuous through the tank side, or, as it is more usually called, the tank margin plate. But generally the frame bar, especially in vessels now fitted with these tanks, is cut at the tank margin plate, and a continuous angle bar fitted, making the connection between the tank side and the outer shell plating watertight.

The continuity of the transverse frame strength in such cases is maintained by connecting the frame legs to the tank side by large bracket plates.

Though M'Intyre tanks are less adopted than formerly, they are still fitted in some cases. Such a tank is illustrated in a midship section, fig. 50.

The double bottom water-ballast tank now most commonly adopted is that known as the "cellular double bottom." The transverse framing of this system (and longitudinal framing dotted) is illustrated in fig. 2.

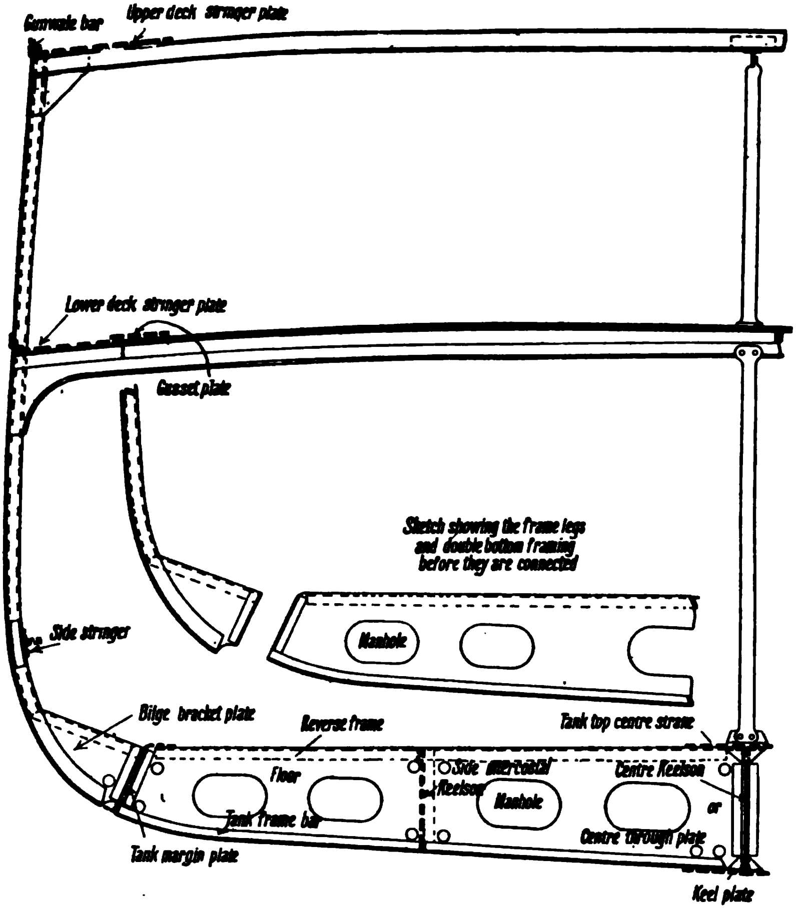

FIG. 2.—Midship Section showing Transverse Framing in a Vessel with a Cellular Double Bottom, also the Longitudinal Framing (dotted).

Examination of the diagram shows the arrangement of the transverse framing to be somewhat interfered with, though, in effect, this modified arrangement is identical in principle with that previously described for vessels with ordinary floors.

The water-ballast tank extends from margin plate to margin plate, and from the keel to the top of the floors. Here we usually find that a continuous deep plate runs fore and aft through the centre of the tank (centre keelson or centre through-plate).

The continuity of the floor plate is necessarily interrupted, but the continuity of the transverse strength is maintained by connecting the floors to the centre through-plate by means of angles. The floors at the middle line are much deeper than required for ordinary floors, thus permitting a good connection, and somewhat compensating for the break in the continuity of the frames and reverses. The outer ends or extremities of the floors, called bracket plates, extend to exactly the same height as in similar ships with ordinary floors. But again, at the bilge, we observe that, in order to form the outer boundary of the cellular bottom tank, the floors have to suffer interruption in continuity in order to allow the margin plate to pass continuously fore and aft, and fit hard on to the shell plating. However, by means of angle connections, and a considerable depth of floor at this place, a minimum for which is definitely fixed by each classification society (margin plate width), a good connection is made to the bracket plate, or tank knee as it is sometimes called, and the shape of the floor is preserved to the height prescribed.

In order to ensure the watertightness of the tank at this place, a continuous bar is fitted to the lower extremity of the margin plate, to connect it to the outer bottom. This necessitates another break in the continuity of the frame bar. The depth of the floor plate, however, enables a satisfactory connection to be made between the transverse framing inside and outside of the tank, by means of the bracket plate already mentioned. In exceptional cases the frames have been preserved continuously from keel to gunwale, and the watertightness at the margin plate effected by fitting angle collars round the frames for the whole length of the tank. The reverse bar is also intercostal between the centre keelson and the margin plate, and then again commencing outside the margin plate, is continued along the upper edge of the bracket plate, and up the frame bar to its prescribed height.

In all other respects, the upper framing, beams, pillars, and their connections are identical with those in the ordinary system previously referred to in fig. 1.

Regulations for increasing the Number of Tiers of Beams.—So far, we have only dealt with a small type of vessel requiring but two tiers of beams. As vessels increase in size, however, not only for convenience and adaptation for carrying cargo, but for reasons of structural strength, more tiers of beams, which may or may not be sheathed with a wood or steel deck, are introduced. If the vessel is classed, these are regulated by the rules of the classification society. Thus, we find that ssels classed at Lloyd's, when over 15 ft. 6 in. from top of keel to top of per deck beam at centre, require, in addition to the weather deck, an tra tier of beams in the hold, which may be widely spaced—on every tenth frame (see fig. 1); and when 24 ft. is exceeded, still another tier of beams is required.

Compensation for dispensing with Hold Beams.—The introduction of an extra tier of beams in a ship of, say, 16 ft. in depth, may, however, prove a source of inconvenience to a shipowner in the stowage of certain kinds of cargo, and a similar inconvenience may also arise in the introduction of the third tier of beams in a vessel of, say, 25 ft. depth.

In such cases, by modifying the transverse framing, these lowermost tiers of beams could be dispensed with, in the manner illustrated later in this chapter. First of all, we observe that these additional tiers of beams are required for purposes of strength. With ships of greater depth, and naturally, we infer, of greater breadth, the increased immersion produces vastly increased external water pressures, tending to crush in the bottom and sides of the vessel.

Moreover, the loading of heavy cargo tends to distort the transverse form. Thus additional tiers of beams, supported from keel to uppermost deck by pillars, become necessary, unless a satisfactory method of compensation can be provided. This can be done by increasing the strength and rigidity of the transverse framing, the details of which methods are fully described a little later.

Longitudinal Framing.—We have already observed that the special function of transverse framing is to preserve the transverse form, when experiencing the numerous and ever-varying stresses to which ships are subject. In a like manner, and to a much greater extent, especially in vessels of great length, there is the tendency to alter in longitudinal form, as, in their pitching movements, they are subject to immense differences and sudden changes in the buoyant support afforded by the water, and to sudden twisting stresses when crossing skew seas. Moreover, such stresses may be greatly increased, especially under certain conditions, by the filling of large peak or other ballast tanks at the ends of a vessel, or in stowing very heavy cargo towards the extremities.

Of what paramount importance does an efficient arrangement of longitudinal framing become, will therefore be obvious. Thus we find that along the bottom, on the bilge, and up the side of a vessel are a number of girders of various forms extending all fore and aft, the continuity of whose strength is most rigidly maintained.

Keelsons and Stringers.—Fig. 3 shows the same section as fig. 1 with the longitudinal framing introduced. We may notice that all longitudinal girders of whatever form, on the bottom of the vessel between bilge and bilge, are termed *keelsons*, and those on the sides above the bilge, *stringers*. The name given depends, not so much upon the form of the girder section, as upon the locality in which it is placed. The most important keelson girder is that standing upon the top of the floors at the middle line. It is composed of a vertical plate with two large angles on the top, and the bottom, the whole being mounted by a thick plate called a *ri*

This girder is termed the *centre keelson*, and really forms the backbone of the ship.

In order to prevent the floor plates tripping, that is, inclining either forward or aft, and to afford strength and stiffness to the shell, it is usual to introduce what is termed an intercostal girder or *side keelson*, so named because it is composed of plates fitted intercostally between the floors in a continuous line all fore and aft, and connected to them by angles. In very small vessels, somewhat similar plates are fitted, whose height terminates at the upper edge of the floors. These are named *wash plates*, their function being to prevent any water which may have drained into the bilges dashing from side to side when the vessel rolls. This is also one of the functions of side intercostal keelsons. But in larger vessels the plates are carried above the floors between two angles as shown in fig. 3, and thereby con-

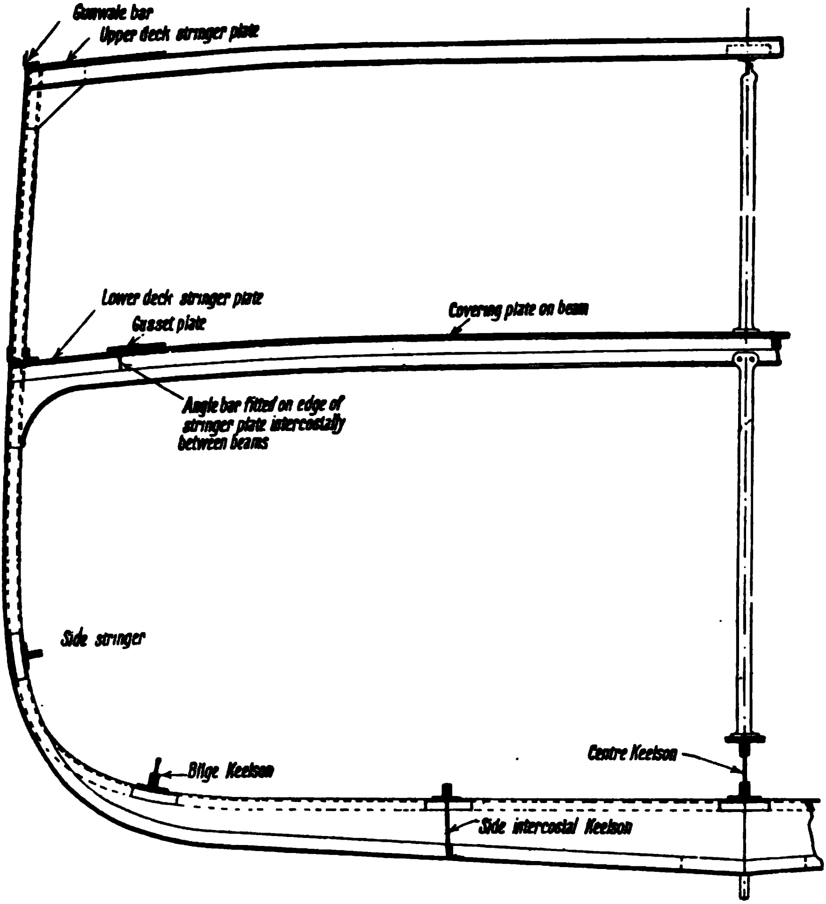

FIG. 3.—Midship Section showing the Longitudinal and Transverse Framing combined, in a Vessel with Ordinary Floors.

verted into a continuous keelson. Keelsons may be built up in a variety of ways according to the dimensions and proportions of the vessel. These are more fully dealt with in Chapter IV.

The next girder is on the bilge, and is called a *bilge keelson*. Further up the vessel's side is a small girder, known as a *side stringer* (or it may be an upper bilge stringer).

Deck Stringers.—At the gunwale, and on the lower tier of beams, are broad continuous plates fitted on the ends of the beams. These are *deck stringer plates*, and form most valuable girders in conjunction with the beams. Wherever a tier of beams is fitted, whether a wood or steel deck is, or is not laid, this thick stringer plate is always to be found.

Centre Through-Plate.—In fig. 2 the longitudinal girders are shown (dotted lines) in conjunction with the transverse framing of the double bottom. Extending continuously down the middle line, and standing on the plate keel, is a deep plate, of the depth of the floors and tank. Indeed, the depth of the floor is regulated by the depth of this plate, the minimum width of which is fixed by the classification society. Two large angles on the top and bottom, mounted by a thick plate forming part of the tank top, make up the combination forming the *centre keelson*. It is also known as the *centre through-plate*, or *centre girder*.

Intercostal Keelsons.—The next girder is usually intercostal, the floors being continuous, as a general rule, in merchant vessels. This is known as a *side* or *intercostal keelson*. Its continuity is maintained by connection to the floors by means of angles.

Margin Plate.— At the bilge is the tank side, or margin plate, extending continuously fore and aft. This naturally forms an efficient bilge keelson, though not known by that name. Above the bilge, the arrangement of stringers is similar to that for the ship with ordinary floors.

Necessity of thorough Combination of Transverse and Longitudinal Framing.—Even viewed separately, although both the transverse and longitudinal framing are absolutely essential for the work to be done, yet neither could possibly perform its own duty without the aid of the other. Whenever a longitudinal girder crosses a transverse frame, it ought to be carefully and thoroughly connected to it, if necessary, by the aid of small pieces of angle iron, or lugs, as they are often termed. For instance, in fig. 3 we find that the centre keelson is riveted to every reverse frame that it crosses on the top of the floors by means of its own bottom bars. But in order to get a doubly secure connection, a short piece of reverse bar (lug piece) is riveted to the other side of the floor, through the horizontal flanges of which the bottom bars of the keelson are riveted also. This same lug forms the covering piece for the reverse frame butt. The same principle of connection is applied to all the other keelsons and stringers wherever practicable.

Structural Value of Shell Plating.—When the skin, or shell plating, is worked over this framework, the effect is an enormous contribution to both transverse and longitudinal strength by more effectually binding together the whole structure into a single compound girder. Such a mode of construction, where one part is interdependent upon another for the utmost development of its own strength and rigidity, must commend itself.

Fig. 5 shows the vessel whose framing has been illustrated in figs. 1 and 3 with the shell plating in addition; and similarly fig. 6 shows the vessel whose framing has been illustrated in fig. 2, with the modification in the framing caused by the hold beams being dispensed with and web frames and stringers introduced as compensation.

The transverse framing stiffens and assists the longitudinal, and the longitudinal stiffens and assists the transverse, in doing each its own work. The whole system of the structural work of a ship is based upon the principle that unity is strength. Each of the innumerable parts performs its work in conjunction with the adjacent parts to which it is closely related, thereby contributing to the perfection of the efficiency of the ship girder. Thus many severe stresses, which would at first appear to be of a local character, become general, simply because the particular part upon which, perhaps, they are first experienced, communicates a share of the stresses through the other girders which cross and are attached to it, to the area around. In this manner the stress is distributed over the structure, its local severity reduced, and the possibility of evil results minimized.

Fig. 4 is a midship section of a large vessel, showing the longitudinal and transverse framing and the shell and deck plating. It also furnishes the name of each structural part, which no doubt may be of assistance to many readers in traversing the following pages.

ALTERNATIVE MODES OF CONSTRUCTION.

Assuming, in the case of a vessel to be classed 100 A1 at Lloyd's, that all the preliminary work of fixing the dimensions and getting out and approving of the design and general arrangement has been satisfactorily concluded, before any steps can be taken in the work of construction, structural plans must be prepared by the shipbuilder, and submitted for the approval of Lloyd's Committee. These plans usually consist of a midship section, which gives a transverse view of the structure of the vessel amidships; a profile, showing a longitudinal sectional elevation (see figs. 13 and 14); and a deck plan; and upon these plans the sizes or scantlings of all iron, steel, or wood, forming structural parts of the vessel, are distinctly marked according to the requirements of Lloyd's Rules.

As we have previously observed, in the case of a classed vessel the responsibility of structural strength in relation to the weight to be carried, is borne by the classification society; hence both builders and owners are relieved from this, so long as the workmanship is of a thoroughly satisfactory nature. However, as the classification societies provide alternative modes of arriving at the required structural strength, the owner has the option,

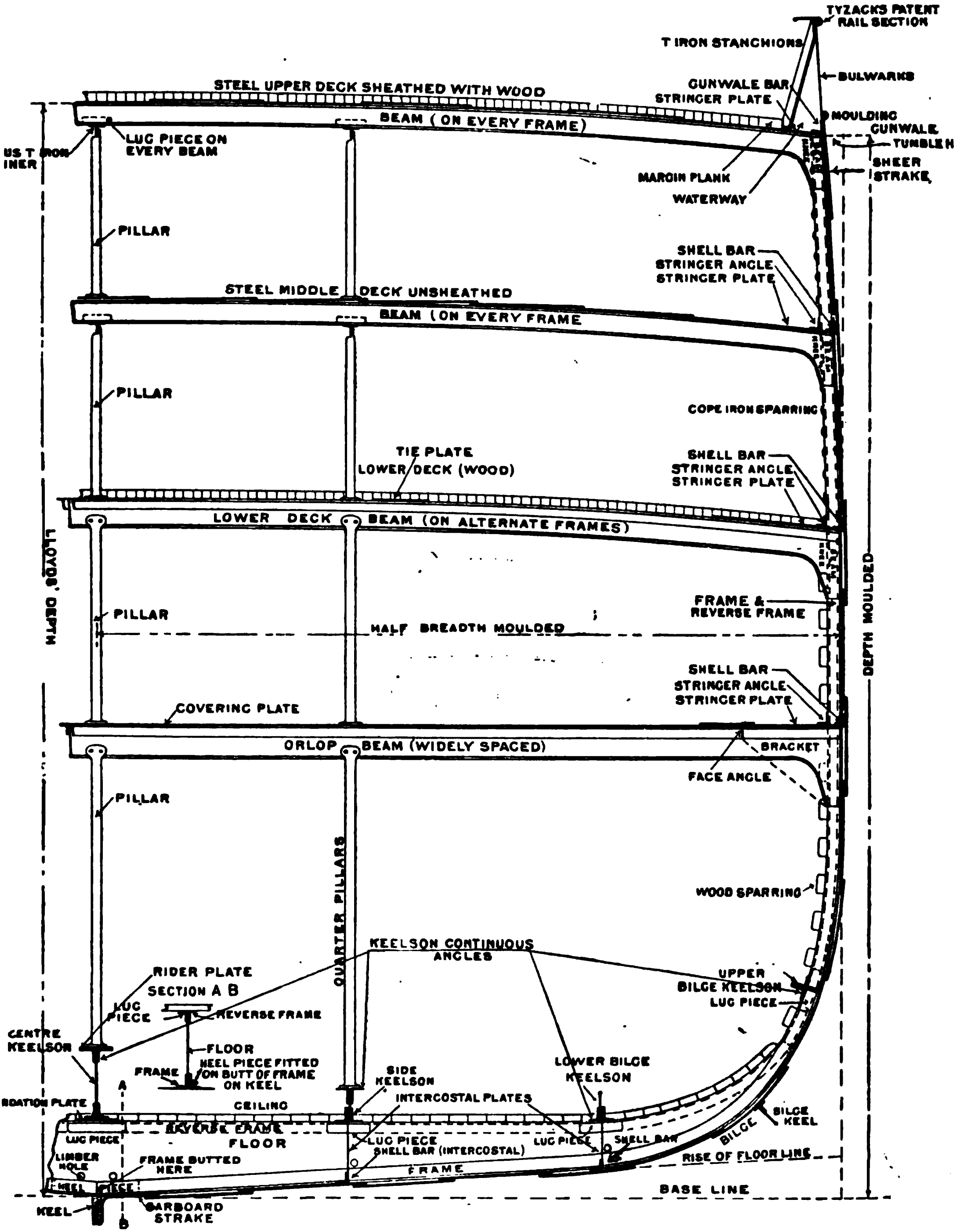

FIG. 4.—Midship Section of Merchant Steamer, giving Names of Parts and illustrating Comr

under the guidance and advice of his naval architect, of making the choice of the system most suited to his requirements.

A ship is a girder composed of a host of smaller girders which comprise the framework. In the nature or the design of the framing the shipowner is free, to some extent, to exercise his choice. This can probably be best illustrated by the aid of the diagrams figs. 5, 6, and 7.

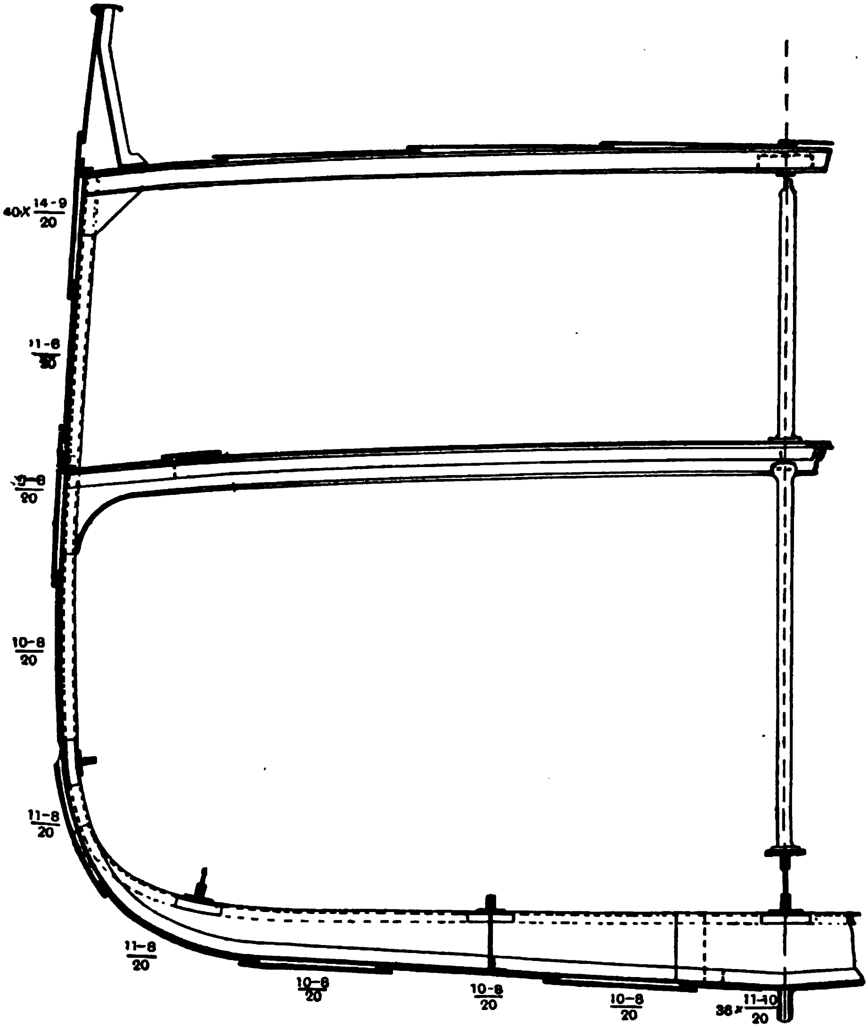

Fig. 5.—Midship Section of Vessel requiring two Tiers of Beams with Ordinary Frames and Floors.

With Hold Beams.—Fig. 5 is a midship section of the vessel whose transverse framing we have already examined in fig. 1. She has a bar keel, and is built on the ordinary floor system. Being over 15 ft. 16 in. in depth from the top of the keel to the top of the upper deck beams at centre with the normal amount of camber, this vessel requires two tiers of beams. But while the beams in the upper tier are placed on every frame (2 ft. apart), the beams in the lower tier, which are exceptionally strong, are only required on every tenth frame (20 ft. apart). The transverse framing, supporting the side shell plating, is made up of two angle bars (the frame and reverse frame) fitted back to back, and the longitudinal frame girders are as shown in the section.

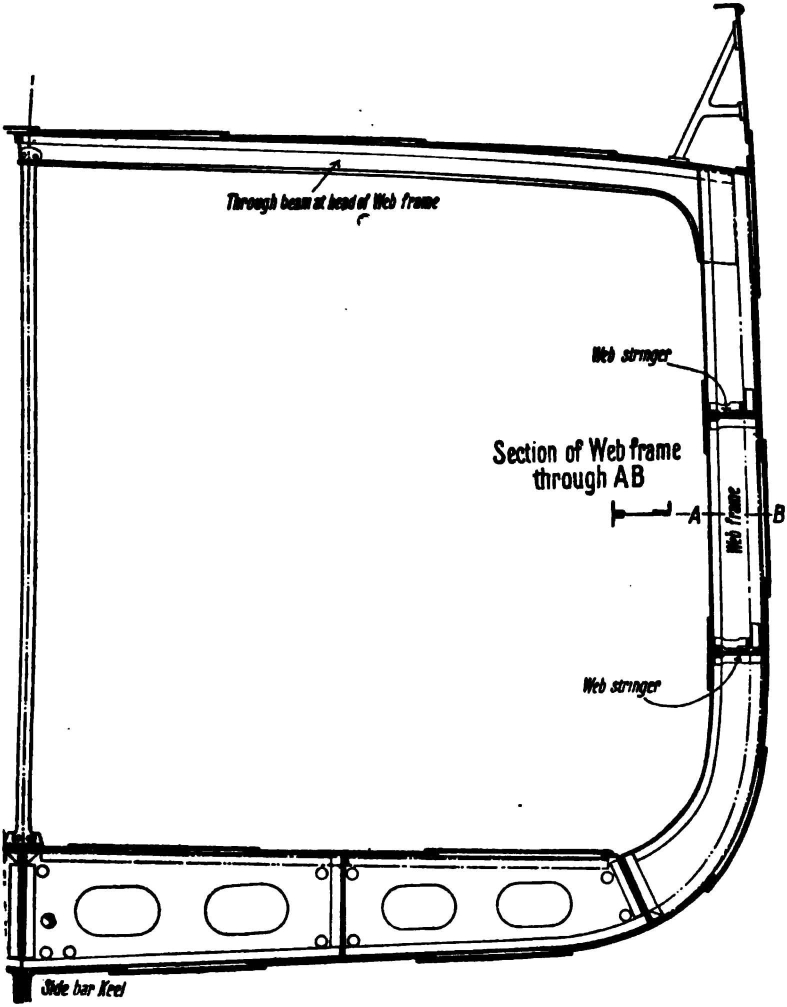

Fig. 6.—Midship Section showing Hold Beams dispensed with, and Compensation in the form of Web Frames and Stringers introduced.

Web Frames in lieu of Hold Beams.—Fig. 6 is a midship section of the same vessel as shown in fig. 2, and is of exactly the same dimensions and external form as fig. 5. In this case, the vessel has a side bar keel, and is fitted with a double bottom. The hold beams are dispensed with, and in lieu of them, transverse web frames are spaced on every sixth frame throughout the vessel's length. A section at a web frame is shown. It consists of a web of plating 15 in. wide, extending from the tank side to the upper deck beams. It is attached to the shell plating by an angle of ordinary frame size, and has two smaller angles fitted on its inner edge, or a single bar of larger size (equivalent sectional area) may be substituted. (When there is no double bottom, the web frame blends into the ordinary floor, and forms a complete continuous girder from gunwale to gunwale, and the transverse frames between the web frames are similar to those shown in fig. 5.) The longitudinal framing consists of two web stringers fitted intercostally between the web frames. When the beams at the head of the web frames are continuous from side to side, they are fitted of extra strength, but elsewhere they are similar to the upper deck beams shown in fig. 5.

Deep Framing in lieu of Hold Beams.—In fig. 7 the hold beams are again dispensed with, and compensated for by adopting what is known as deep framing. These deep frames, unlike the web frames, are upon every frame, and are made up of two large angles fitted together as shown on the midship section, fig. 7, which, in combination with the side stringers, possess strength and rigidity fully compensating for the omission of the hold beams.

Z frames and bulb angles may be, and frequently are, substituted for the form of deep framing just described, in which cases the deep Z's should be $\frac{1}{20}$ in. thicker, and the bulb angles $\frac{2}{20}$ in. thicker, than is required for deep frames, and of the same depth (depth here means distance from heel of frame to heel of reverse, AB in fig. 7). These additions to thickness make the three sections of framing of practically equivalent efficiency.

Several alternative forms of side stringers may be adopted, one of which is shown in the diagram fig. 7. It may also be pointed out that, when the deep frame system is adopted, the tank bracket knees should be of extra depth, so as to provide ample support to the bilge, and the beam knees should be three times the depth of the beam. This somewhat cumbrous system of side stringers (fig. 7) has already been largely superseded by a much simpler, lighter, and more compact form of stringer, as illustrated in figs. 45, 52, 58, 60, etc., in which cases the main frames are slightly heavier as compensation.

The adoption of any one of the foregoing systems of framing would in no way interfere with a vessel's obtaining the highest class with any classification society. On coming to vessels of larger dimensions than the one with which we have been dealing, it is natural to expect that the depth and thickness of the transverse framing should increase, and that a greater number of side stringers should be required. But as soon as the depth exceeds 24 ft., we have seen that an extra tier of beams is required, and the vessel, assuming that full scantlings have been adopted, becomes of "three deck" type.

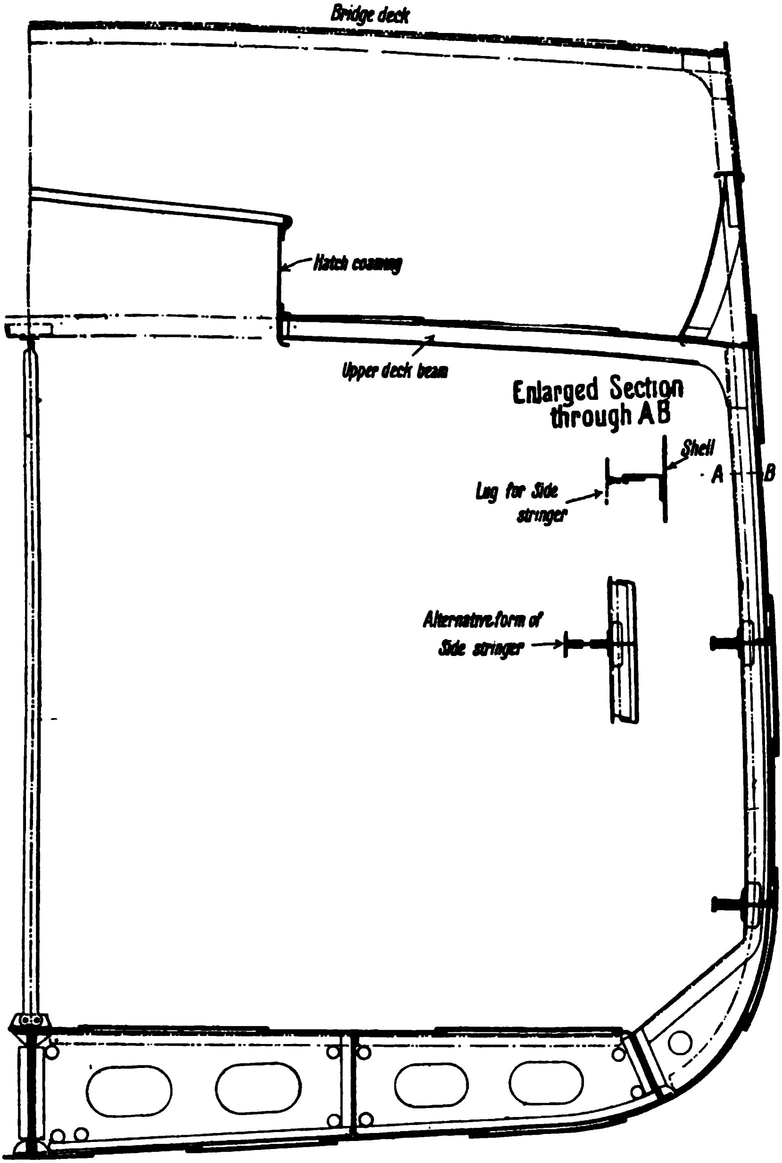

FIG. 7.—Midship Section showing Hold Beams dispensed with, and Compensation in the form of Deep Framing introduced. (See page 20 *re* further modification in Side Stringers.)

However, that the vessel will have three tiers of beams does not necessarily follow; for, just as in a two deck vessel the lower tier of beams may be dispensed with, in like manner, the lowest tier in a "three deck" vessel may be dispensed with by fitting in lieu, either web frames up to the middle deck, or deep framing.

Fig. 13 shows the transverse framing of a "three deck" vessel of 34 ft. depth from keel to upper deck (not shelter deck) beam at centre (having the normal camber), with deep framing in place of the omitted hold beams.

Compensation in lieu of a Tier of Closely Spaced Beams and a Steel Deck.—Figs. 59 and 60, etc., illustrate the construction of a vessel of 27 ft. 7 in. moulded depth, *i.e.* a vessel belonging to the "three deck" class. By ordinary rule she requires two steel decks and a tier of widely spaced hold beams. The lower steel deck, however, with its tier of closely spaced beams, has been entirely dispensed with, compensation (in addition to deep framing) being introduced chiefly by fitting large curved web frames in conjunction with each strong hold beam and its broad stringer plate, as shown. See fuller description, page 88.

Compensation in lieu of Hold Pillars.—So seriously is the stowage of many cargoes interfered with by the usual system of numerous hold pillars at the centre line fore and aft, and in vessels of great beam by having pillars at the quarter breadth also on each side, that it is not surprising in recent years that attempts should have been made to get rid of these obstructions as far as possible. In the cargo vessel illustrated in figs. 53 and 54, the hold pillars are entirely dispensed with, saving one pair, or at most two pairs, of extra strength to each hold; see detailed description, page 81.

The steam collier illustrated in figs. 57 and 58 has no pillars whatever at the sides of the extremely large hatches for self-trimming, the support in this case being obtained by large bracket plates; see description, page 87.

Then, again, the ingenious builders of the turret steamer (Messrs Wm. Doxford & Sons, Ltd.) have arrived at a system of construction whereby neither hold pillars nor hold beams are necessary. The details of the construction of these beamless and pillarless steamers, and the compensation introduced for such omissions, is fully described on pages 71, 72, etc., and illustrated in fig. 44. See also Cantilever Framed Steamer, page 78 and fig. 52.

Side Stringers entirely dispensed with.—Fig. 61 illustrates a bold innovation in the practice of shipbuilding—side stringers being entirely omitted. A description of the construction of these vessels will be found on page 91.

Numerals for Scantlings.—In order to ascertain the scantlings of the material shown on the plans submitted to Lloyd's Committee, their rules give the following instructions :—

Assuming that the vessel is to be of full strength, with, therefore, maximum rule scantlings,—add together (measurements being taken in feet) the girth of the half midship frame section of the vessel, measured from the centre line at the top of the keel to the upper deck stringer plate; half the moulded breadth; and the depth (Lloyd's). The sum of these numbers gives what is known as the *1st numeral.* By multiplying the 1st numeral by Lloyd's length, the *2nd numeral* is obtained. By means of the 1st numeral, the sizes and thicknesses of all frames, reverse frames, depth and thickness of ordinary floors, thickness of bulkheads, and diameter of pillars are found from the tables in Lloyd's Book of Rules.

The greatest breadth of the vessel at each deck regulates the size of the beams for each respective deck.

The depth of the vessel regulates the number of tiers of beams, and the number of stringers. The 2nd numeral, both alone and in conjunction with the proportion of length to depth, regulates all the remaining scantlings, and the number of complete or partial steel or iron decks. It should be noted, however, that for vessels of over 24 ft. in depth (Lloyd's)—"three deck," notwithstanding the fact that the lowest tier of beams may be dispensed with by making compensation in some form or other—the *1st numeral* is obtained *by deducting* 7 from the sum of the half girth, half moulded breadth and depth; and the *2nd numeral* by multiplying the 1st numeral thus obtained by the length in the usual way. For the lighter types of vessels, known as "spar" and "awning" deck, the 1st numeral is obtained by adding together the half girth and Lloyd's depth taken to the *main* deck (see fig. 9), together with the half moulded breadth, and the 2nd numeral is the product of the 1st numeral by the length of the vessel. (See fig. 4 for Lloyd's depth.)

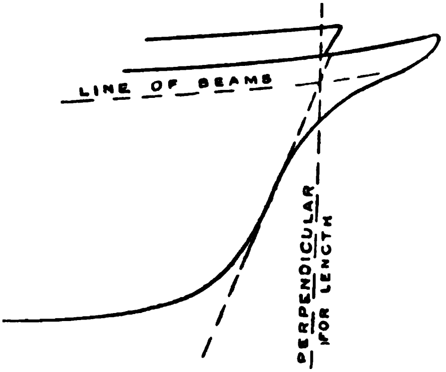

FIG. 8.—Length between Perpendiculars.

In the book of Lloyd's Rules, these numerals are all arranged in a graduated tabular form, and adjoining them is given the scantling of the material, or structural item or items which they govern. By referring to these rules, and the notes accompanying them, the particulars of scantlings given along with the midship section, fig. 5, are found, as are also the tables of scantlings on pages 30 and 31.

After considering the special features of the vessel in question, and adjusting the scantlings where necessary, the plans are returned to the shipbuilder, who sees to the ordering of the steel and iron, and whose draughtsmen proceed with the work of drawing the detail structural plans for the workmen in the shipyard.

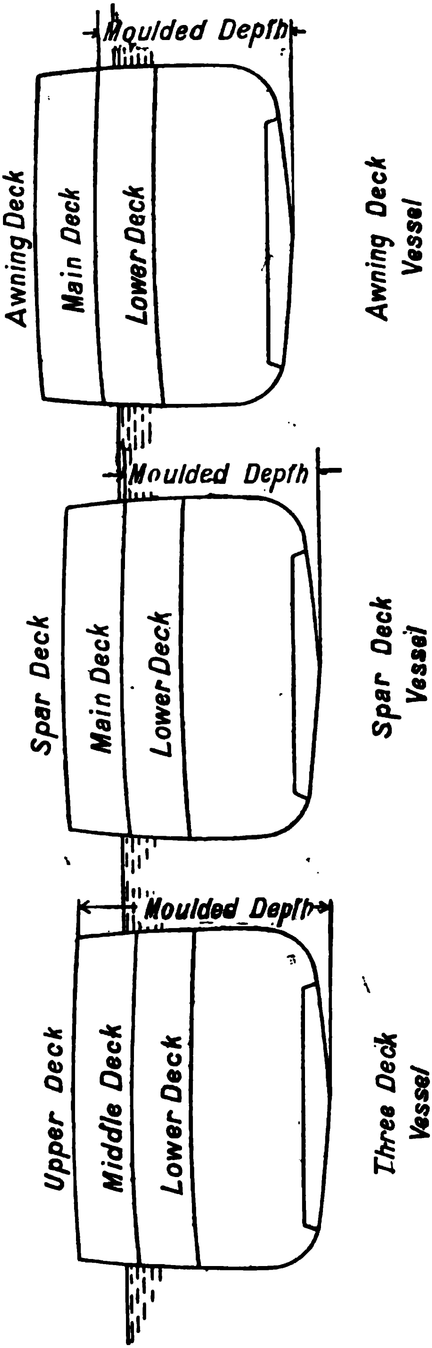

Fig. 9.

Definitions of Important Terms.

1. **Length between Perpendiculars.** — This is the length usually agreed upon by shipowner and shipbuilder when contracting for a new vessel, and is that generally understood when speaking of the length of a vessel. For vessels with straight vertical stems, it is taken from the foreside of the stem bar to the aft side of the stern post. When the stem is raked, that is, inclined forward, from the foot, the length is measured from the fore side of the stem bar at the upper deck. Should the vessel have a clipper or curved stem, the length is measured from the place where the line of the upper deck beams would intersect the fore edge of the stem if it were produced in the same direction as the part below the cutwater (see fig. 8).

2. **Length over all** is the length measured from the foremost tip of the stem bar to the aftermost tip of the overhang of the stern. For vessels with straight stems it is practically the extreme length.

3. **Lloyd's length** is the

same as the length between perpendiculars, except that the length is taken from the after side of the stem to the fore side of the stern post.

4. **Registered length** is measured from the fore side of the tip of the stem bar to the after side of the stern post.

5. **Extreme breadth** is measured over the outside plating at the greatest breadth of the vessel. This is also the **Registered breadth.**

6. **Breadth moulded** is taken over the *frame* at the greatest breadth of the vessel.

7. **Depth moulded** is measured in one, two, and three deck vessels at the middle of the length, from the top of the keel to the top of the upper deck beams at the side of the vessel. In spar and awning decked vessels, the depth moulded is measured from the top of the keel to the top of the main deck beams at the side of the vessel (see fig. 9).

8. **Lloyd's Depth.**—This is somewhat different. It is required that all upper decks, and all main decks in spar and awning decked vessels (see fig. 9), have a round upon them, the height of which at amidships amounts to a quarter of an inch for every foot of the greatest breadth of the deck. This is termed "camber," "round up," or "round of beam." This is added to the moulded depth, and gives Lloyd's depth. With this modification, it is otherwise the same as No. 7.

9. **Depth of Hold.**—This is measured from the top of the ceiling at the middle of the length in vessels with ordinary floors, or from top of ceiling on double bottoms, if ceiling is laid, or from the tank top plating when no ceiling is laid—to the top of the beams of upper, spar, or awning decks. This is also the **Registered depth** (about 2½ in. is the usual allowance for ceiling).

10. **Extreme Proportions.**—A vessel is said to be of extreme proportions when her length exceeds eleven times her depth (moulded depth plus camber). Under such circumstances, additional longitudinal strength is required over and above that necessary when of ordinary proportions.

CHAPTER III.

TYPES OF VESSELS. SECTION I.

Fundamental Types and Modifications of same—Relation between Deck Erections and Deadweight—No Reduction in Freeboard for Excessive Strength in a Vessel with Full Scantlings—Determination of Type—Three Deck, One and Two Deck, Spar and Awning Deck Vessels—Illustration of Principal Scantlings of foregoing Types—Vessels of Intermediate Grades between Three Deck and Spar Deck, and Spar Deck and Awning Deck—Raised Quarter Deck Vessels—Maximum Stress—Partial Awning Deck, Shelter Deck, Well Deck, Shade Deck Vessels, etc.

Fundamental Types of Vessels.—The great variety of purposes for which ships are used, and the widely different kinds and densities of cargoes which may be carried, have had the very natural effect of producing vessels specially adapted for specific purposes. And thus, while ordinary mercantile steamers may generally be classed under the heading of cargo or passenger steamers—wholly or partially—much greater subdivision of type is adopted. Hence ship-folk are in these days familiar with the three principal or fundamental types of vessels—

(1) *Vessels of full scantlings, known as Single, "Two," or "Three Deck,"*
(2) *Spar Deck Vessels,*
(3) *Awning Deck Vessels,*

and also with modifications of these types, such as *Raised Quarter Deck Vessels*, *Partial Awning Deck Vessels*, *Shelter Deck Vessels*, *Shade Deck Vessels*, and in addition, vessels of more novel type, such as "*Turret*," "*Trunk*," and other "*Self-trimming*" steamers.

In this section it is purposed, by means of description and illustration where necessary, to point out the special features in either design or structure which produce the distinctions in these different types.

We have previously shown, in dealing with the subject of classification, that the load line is assigned to a vessel strictly in proportion to her structural strength with a minimum percentage of reserve buoyancy. This, it will be understood, applies to every kind of vessel to which a minimum freeboard is assigned.

Relation between Deck Erections and Deadweight.—Now, assuming that a flush deck vessel has been built to the highest standard of structural strength, it will follow that no reduction can be made in the freeboard unless additional reserve buoyancy, suitably situated, can be added to the vessel. But as valuable additional buoyancy can be obtained in the form of forecastles, bridges, poops, and other superstructures covering either the whole or part of the length of the vessel, reductions in freeboard, which may considerably augment the deadweight carrying capacity of the vessel, are obtained.

No reduction in freeboard for excessive strength in a vessel of full scantlings.—Again, taking the case of a flush decked vessel (with no erections whatever) built *in excess* of the highest standard of structural strength, no concession could be obtained in the matter of freeboard, simply because, as we have pointed out, such a vessel would have a less percentage of reserve buoyancy than required by the freeboard tables of the Load Line Act of 1890. And as seaworthiness embraces other features in addition to structural strength (and equally important), to jeopardise the safety of a vessel by allowing to her the maximum immersion which a consideration of her structural strength alone would permit, would be exceedingly unwise. One of these important features which is vastly influenced by the amount and disposition of the reserve buoyancy is the stability, and in drawing up the "Freeboard Tables," a minimum percentage of reserve buoyancy was specified for flush decked full scantling vessels of ordinary type and proportions such as, it was assumed, would ensure as far as possible favourable stability conditions when properly loaded.

With these points kept in view, together with what has already been said upon "Classification," we shall better be able to see how the different types and modifications of types of vessels have arisen.

The Determination of Type.—Every reader knows that there are many bulky cargoes of such comparatively small density that a vessel could be loaded up to her hatches, and every available space in deck erections occupied, and the total deadweight would not be sufficient to immerse her to the maximum draught; while, on the other hand, there are other cargoes of vastly greater density with which the same vessel could be brought to her load draught long before the total hold space had become occupied. To such variations in the specific gravity of cargoes are principally due the types known as awning deck, spar deck, and vessels of full scantlings.

"Three Deck" Vessels.—Let us first suppose that a shipowner contemplates the addition of a new vessel to his fleet. We now see that he has more to consider than merely external dimensions and speed. He must be satisfied in his own mind, to some extent at any rate, as to what is the most probable kind of cargo this vessel will carry. If the probable cargo be of considerable density, it will naturally follow that it will be impossible, as with many of such cargoes, to fully occupy the whole hold space before the vessel has reached her load water-line. He will therefore want that type of vessel which will carry the greatest deadweight in relation to her size; and, as we have seen, the strongest type of vessel built, and that which permits of the greatest immersion (*i.e.* to which the least freeboard is assigned), is that known as the "three deck" vessel, though it is not actually necessary, as before shown, that the vessel should possess three actual tiers of beams, for the lowest tier may be dispensed with by introducing compensation in the form of deep framing, web framing, etc.; or the two lower tiers of beams may be substituted by one tier of widely spaced beams of extra strength, together with deep framing assisted at intervals by deep web frames, as described on page 89, and illustrated in figs. 59 and 60.

One and "Two Deck" Vessels.—Vessels of smaller size, though built to the fullest scantlings, may only require two, or even one tier of beams.

The amount and nature of erections on vessels of this kind, as for three deck vessels, would probably depend chiefly upon the requirements for the accommodation of the crew, protection of steering gear, and, as in the case of three deck vessels, upon the proportions chiefly in relation to the depth to length. Even in the case of erections such as those just mentioned, considerable reduction may be obtained in the freeboard (which means increased deadweight) according to the value of the reserve buoyancy afforded by such erections.

Awning Deck Vessels.—Supposing, again, that the shipowner required a vessel to carry cargo of comparatively light density, or, say, to carry cargo in the lower holds, with passengers in the 'tween decks and other superstructures, it is obvious that the "three deck" vessel of full scantlings would be unsuitable for the purpose, for not only would he find it impossible to bring the vessel down to her load draught line with ordinary miscellaneous cargo, but the excessive strength of the vessel would have entailed much unnecessary outlay in the first cost, and excessive and therefore unnecessary structural material is both useless and waste. Under such circumstances the light awning deck type of vessel would probably be adopted, which, possessing large freeboard, that is, high side out of water, would have the additional advantage of being drier on deck, and therefore better adapted to the comfort and requirements of passengers. (See page 37 *re* Modern Awning Deck Vessels.)

Spar Deck Vessels.—Intermediate between the three deck vessel of full scantlings and the awning deck vessel of greatly reduced scantlings, comes the spar deck type of vessel, which is particularly suited for cargoes of moderate density. In recent years this type has been extensively adopted. All other vessels, whether they be called shelter deck vessels, shade deck vessels, raised quarter deck vessels, partial awning deck vessels, or vessels of special design for self-trimming purposes, may, from a structural point of view, be assigned to one of the fundamental types, though modified in certain of their structural features in a greater or less degree.

The external view of the structure of a vessel, such as may be obtained as she lies afloat unloaded, or in dry dock, affords little indication whether she be of "three deck," spar deck, or awning deck type. However, in a fully loaded condition, the amount of freeboard would present a more certain clue to the determination of her type.

Closer Examination of Types.—It will be necessary at this stage to examine the structural features of these different types of vessels in more minute detail.

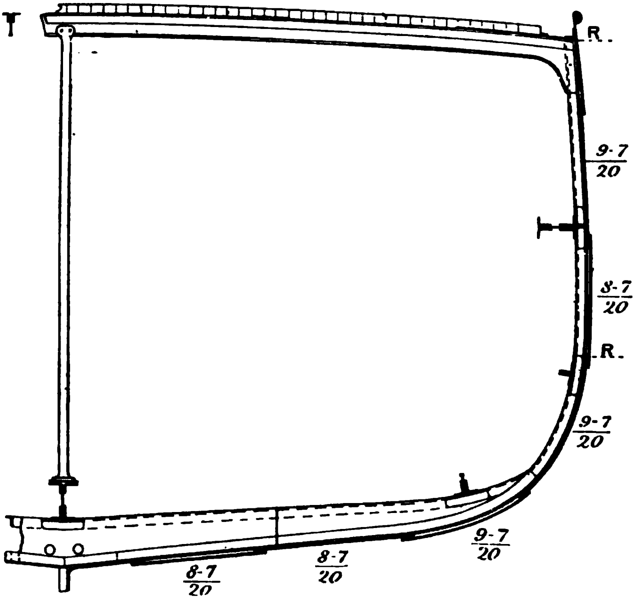

FIG. 10.—Midship Section of a Single Deck Vessel.

VESSELS OF FULL SCANTLINGS.

First. One and "Two Deck" Types.—See fig. 10, which is a midship section of a single deck vessel.

See also fig. 5, which is a midship section of a two deck vessel, built with ordinary frames and widely spaced hold beams; fig. 6, which is a midship section of the same vessel with web frames compensating for hold beams; and fig. 7, which is also the same vessel built with deep framing, likewise dispensing with hold beams.

The sectional profile of the "two deck" vessel shown in fig. 11 is for the same vessel to whose midship section we have just referred in fig. 7.

The following Tables of Scantlings for figs. 5, 6, and 7 (and 11) will give, to those readers unacquainted with the rules of the classification societies, some idea of the sizes of material required for vessels of this size. The scantlings are such as would comply with Lloyd's present requirements for 100 A1 class.

Scantlings for Fig. 5.	Scantlings for Fig. 6.	Scantlings for Fig. 7.
Lloyd's Numerals*—		
½ Girth, ... 34·4	Same as for fig. 5.	Same as for fig. 5.
½ Breadth moulded, 17·75	,, ,,	,, ,,
Depth, ... 20·00	,, ,,	,, ,,
1st number, . . 72·15	,, ,,	,, ,,
Length, . . . 241	,, ,,	,, ,,
2nd number, . 17,388·15	,, ,,	,, ,,
Depth in length = 12·05	,, ,,	,, ,,
Frames, 4½ × 3 × $\frac{8-7}{20}$.	Frames outside tank, 4½ × 3 × $\frac{8-7}{20}$. Web frames, 15 × $\frac{8-7}{20}$; angles, 3 × 3 × $\frac{7}{20}$ six frame spaces apart (12 ft.). Frames in double bottom, 3 × 3 × $\frac{8-7}{20}$.	Depth of frames 7 in., composed of two angles, 5 × 3 × $\frac{8-7}{20}$.†
Frame spacing, 24 in.	Same as for fig. 5.	Same as for fig. 5.
Reverse frames, 3 × 3 × $\frac{7}{20}$.	,, ,,	See frames.
Floors, 22½ × $\frac{9}{20}$.	Floors, 36 in. deep × $\frac{7}{20}$.	Same as for fig. 6.
Centre keelson, 17 × $\frac{12-10}{20}$.	Centre through-plate, 45 × $\frac{9}{20}$.	Centre through-plate, 36 × $\frac{9}{20}$.
,, angles, 5 × 4 × $\frac{9}{20}$.	Top angles, 3½ × 3½ × $\frac{9}{20}$.	Top angles, 3½ × 3½ × $\frac{9}{20}$.
Rider plate, 11 × $\frac{13}{20}$.		Bottom ,, 4 × 4 × $\frac{10}{20}$.
	Tank margin plate, 25 × $\frac{7}{20}$.	Same as for fig. 6.
	Tank top centre strake, 36 × $\frac{8-7}{20}$.	
	Tank top under engines, $\frac{8}{20}$; and under boiler, $\frac{10}{20}$.	,, ,,
	Tank top in holds, $\frac{7}{20}$.	,, ,,
Side intercostal, $\frac{8}{20}$.	Side intercostal, $\frac{7}{20}$.	,, ,,
,, angles, 5 × 4 × $\frac{9}{20}$.	,, angles, 3 × 3 × $\frac{7}{20}$.	,, ,,
Bilge keelson bulb plate, 9½ × $\frac{9}{20}$.	Formed by margin plate.	Same as for fig. 6.
Bilge keelson angles, 5 × 4 × $\frac{9}{20}$.		

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* See page 32 for explanation of numerals.

† The latest practice is to increase the depth of framing and decrease the scantling of the side stringers, the latter taking the form illustrated in figs. 45, 52, 60, etc. Hence, in the vessel which fig. 7 represents, 7½ in. depth of framing composed of two angles with transverse flanges 5½ in. and 5 in. respectively (3 in. lap), in conjunction with two side stringers (intercostal plate $\frac{8}{20}$ in. thick, and continuous angle on face of frame 5½ × 3½ × $\frac{9}{20}$), would be considered of equivalent efficiency.

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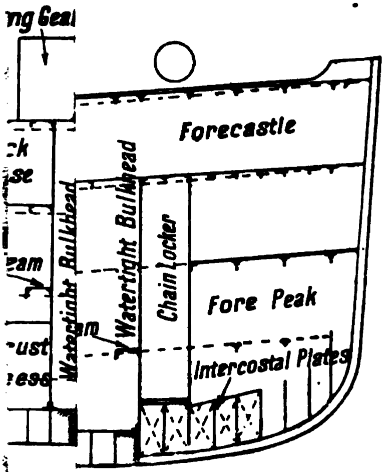

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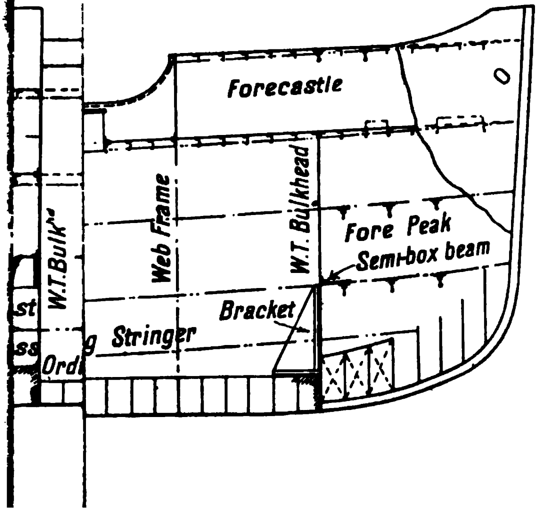

TABLE OF SCANTLINGS—*continued.*

Scantlings for Fig. 5.	Scantlings for Fig. 6.	Scantlings for Fig. 7.
Side stringer, Two angles, } $5 \times 4 \times \frac{9}{20}$.	Two side or web stringers, $15 \times \frac{8-7}{20}$. Angles, $3 \times 3 \times \frac{7}{20}$.	Two side stringers. Plate, $16 \times \frac{10-9}{20}$. Bulb angles, $9 \times 3\frac{1}{2} \times \frac{13-12}{20}$, or, alternate method, Plate, $20 \times \frac{8-7}{20}$. Angles, $5\frac{1}{2} \times 4 \times \frac{9}{20}$. See footnote, page 30.
Upper deck beams, $5\frac{1}{2} \times 3 \times \frac{8}{20}$. Bulb angle. 2 ft. apart.	Upper deck beams $6 \times 3 \times \frac{8}{20}$; bulb angles on every frame. Whole beams at head of web frames, $8\frac{1}{2} \times \frac{8}{20}$ bulb plate and two angles, $3 \times 3 \times \frac{7}{20}$.	Same as for fig. 6. ,, ,,
Lower deck beams, $9\frac{1}{2} \times \frac{9}{20}$. Bulb plate. 18 ft. apart.	None. ,,	None. ,,
Angles, $4 \times 4 \times \frac{8}{20}$.	,,	,,
Covering plate, $\frac{8}{20}$.	,,	,,
Upper deck stringer, $34\frac{1}{2} \times \frac{13}{20}$.	Same as for fig. 5.	Same as for fig. 6.
Lower ,, ,, $32 \times \frac{9}{20} - 25 \times \frac{8}{20}$.	None.	None.
Pillars, hold, $3\frac{3}{8}$.	Pillars, $3\frac{3}{8}$.	Same as for fig. 6.
,, 'tween decks, $2\frac{5}{8}$.	None.	None.
Bulkheads, four in number, $\frac{8}{20}$ thick.	Same as for fig. 5.	Same as for fig. 5.
Bar keel, $9 \times 2\frac{3}{8}$.	Keel slabs on sides of centre through-plate 1 in. thick.	Flat plate keel, $36 \times \frac{14-11}{20}$.
Complete steel deck, $\frac{6}{20}$.	Same as for fig. 5.	Same as for fig. 5.
Reverse angles extend to upper and lower decks alternately.	Reverse angles to upper deck and stringer below alternately.	All reverse angles to upper deck, except in the peaks, where ordinary framing is adopted.
See fig. 5 for scantlings of shell plating.		

A single deck steam vessel, according to Lloyd's Rules, is one having a depth from the top of the keel to the top of the beam at the centre (with the normal round up) of less than 15 ft. 6 in., while a "two deck" vessel is one of less than 24 ft. depth. As previously shown, the "two deck" vessel need not necessarily possess two complete decks, for while the upper deck must be a complete deck laid and caulked, the lower deck may only consist of a tier of widely-spaced strong beams, or even these may be dispensed with, if compensation in the form of web frames and stringers or deep framing be introduced.

The 1st numeral, by means of which is obtained the spacing of the frames, and the scantlings of frames, reversed frames and floor plates, the thickness of bulkheads and the diameters of pillars, is determined by adding together in feet the half-moulded breadth of the vessel amidships, the depth at the middle of the vessel's length from the upper part of the keel to the top of the upper deck beams with the normal round up, and the half girth of the midship frame section measured from the centre line at the top of the keel to the upper deck stringer plate.

By multiplying the 1st numeral by Lloyd's length,* the 2nd numeral is obtained, by means of which are ascertained the scantlings of the keel, stem, and stern post, keelson and side stringer plates and angles, the thickness of the outside shell plating; and this 2nd numeral, in conjunction with the proportion of the vessel's length to depth, determines the scantlings of deck stringer plates, thickness and extent of deck plating, and special additions to structural strength which are required when the vessel is of extreme proportions, that is, of over eleven depths to length. All bulkheads extend to the height of the upper deck. When there is an erection in the form of a bridge, poop, or forecastle, all the frames extend to the height of the stringer plate upon the deck of such erections.

In vessels with two tiers of beams, the reversed angles should extend alternately to the upper deck stringer plate, and to the top of the continuous angle bar on the hold beam stringer. Should the hold beams be dispensed with and web frames substituted, the reversed frames will extend to the upper deck stringer plate and to the top of the angle bar on the stringer plate next below it. With deep framing both the frame and reversed frame extend to upper deck. In small single deck vessels, where the numeral is less than 57, the reversed frames may extend to a less height than that just given. As such erections as poops, bridges, and forecastles are only considered as superstructures, damage to which it is not supposed would endanger the safety of the vessel, the thickness of side plating and the scantlings of their beams and stringers are less than are required for the main hull of the vessel.

Second. "Three Deck" Vessels.—In vessels of this type the upper deck is the strength deck. By this we mean that the vessel depends for structural strength upon the material up to and including the upper deck, when she is subject to the various stresses which are experienced in smooth and wave water, in a ballast, or a fully or partially loaded condition. The upper deck, moreover, *must* be considered as the strength deck, because in the event of damage accruing in any part of the structure up to or including that deck, the safety of the vessel may be greatly imperilled. A "three deck" vessel is one of 17 ft. or over in depth from the top of the keel to the middle deck at centre (with the normal round up), or 24 ft. or more to the upper deck at centre.

Here, again, these vessels need not necessarily possess three tiers of beams, for the lowest tier may be dispensed with in a manner similar to

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* See page 24.

that described for the "two deck" vessel. The numerals for scantlings are obtained somewhat differently from the method described for one and two deck vessels. The 1st numeral is obtained by adding together the half-moulded breadth, and the depth and half girth of the midship frame section measured to the *upper* deck. From this sum 7 is deducted, and the result is the 1st numeral. This, multiplied by the vessel's length, gives the 2nd numeral. All bulkheads extend to the upper deck. All frames extend to the upper deck stringer plate, and, where poops, bridges, or forecastles are fitted, to the height of their respective stringer plates. When ordinary framing is adopted, the reversed frames extend alternately to the upper deck, and to the angle bar on the middle deck stringer plate. If the vessel has deep frames, each alternate reverse frame may stop at the middle deck angle, unless, as in figs. 13 and 14, the height of 'tween decks exceeds 8 ft., in which case all the reversed frames extend to the upper deck. The sheer strake is placed at the upper deck.

While the original idea of a "three deck" vessel was one possessing two or more complete decks laid and caulked, and a tier of hold beams, or a substitute for these hold beams, it is now common for some of these vessels to have not more than one laid deck, and whether a steel deck be required will depend upon the size of the vessel's 2nd numeral, and the proportion of depth to length. For example, a "three deck" vessel, with a 2nd numeral of less than 23,000 and under ten depths in length, or 19,000 and under eleven depths, would require no steel deck whatever; and only when the 2nd numeral had reached 25,000, if there be less than ten depths in the length, would one complete steel deck be required. Where, however, a steam "three deck" vessel requires not more than one steel deck, the wood middle deck may be dispensed with by making a small addition to such freeboard as would be assigned in accordance with the Load Line Act to an ordinary "three deck" vessel with the middle deck laid. Should, however, the shipowner object to any increase in freeboard, the middle wood deck may be dispensed with if the frames and reverse frames are of a size such as would be obtained from the 1st numeral without the deduction of 7. Moreover, all reverse frames would be required to extend to the upper deck, or other compensation introduced. See also page 88 and figs. 59 and 60 for description of a "three deck" vessel wherein the middle tier of beams with its steel deck is dispensed with, by the introduction of stronger framing.

The "three deck" vessel illustrated in figs. 13 and 14 has a shelter deck erection extending all fore and aft, and on the shelter deck a bridge erection. So valuable may the shelter deck be in affording longitudinal strength and buoyancy, especially if it be covered with a steel deck as shown in the diagram, that by estimating its value to the whole ship structure, it may be found to merit important consideration in the determination of the load line. See further remarks upon Shelter Deck Vessels, p. 46.

The dimensions of this "three deck" vessel are:—Length between perpendiculars, 443 ft.; moulded breadth, 51 ft. 6 in.; depth moulded, 33 ft.

3 in.; 'tween decks, 9 ft. 4 in. Lloyd's 1st number is 108·55, and 2nd number 47,870. There are 12·8 depths in the length. Some idea of the sizes of the material for such a vessel of the highest class (built in 1900) may be obtained from the following particulars:—

The depth of the deep framing in lieu of the tier of widely spaced strong hold beams is 10½ in., made up of angles $\frac{10 - 9}{20}$ in thickness.

Frame spacing, 26 in.

The longitudinal stringer intercostal plates are 20 in. broad × $\frac{11}{20}$, and the bulb angles 9 × 3½ × $\frac{12}{20}$.*

Upper deck stringer plate 67 in. × $\frac{11}{20}$ for half length amidships to 51 in. × $\frac{9}{20}$ at ends.

Upper deck plating $\frac{9-8}{20}$

„ „ beams, tee bulb, 11 in. × $\frac{10}{20}$.

Middle „ stringer 67 in. × $\frac{11}{20}$ to 51 in. × $\frac{9}{20}$.

„ „ plating $\frac{8-7}{20}$

„ „ beams, 12 in. × $\frac{11}{20}$ in.. tee bulb.

Shell plating. Sheer strake ¾ in. (+ $\frac{2}{20}$ as part compensation for sheer strake doubling) to $\frac{12}{20}$ at ends.

Keel 1 in. (+ $\frac{2}{20}$ as part compensation for keel plate doubling).

Garboard strake ¾ in. (+ $\frac{2}{20}$ as part compensation for keel plate doubling).

Elsewhere, outside strakes $\frac{14-11}{20}$

„ inside „ $\frac{13-10}{20}$.

Centre through-plate in double bottom 48 × $\frac{11 - 9}{20}$.

Floors $\frac{9-8}{20}$.

Shelter deck $\frac{6}{20}$ steel, or $\frac{6}{16}$ iron.

„ beams, 8 × 3 × $\frac{9}{20}$. Bulb angles on every frame.

Shelter deck side $\frac{9}{20}$ (+ $\frac{3}{20}$ as part compensation for sheer strake doubling) to $\frac{8}{20}$ ends.

By reason of the extreme proportions, a doubling is required to the sheer strake for its whole width. This has been dispensed with, and compensation introduced into the upper side plating, as noted in brackets. Moreover, the shelter deck stringer plate has been made of exceptional strength—$\frac{12}{20}$ths, for the same cause.

In addition to the foregoing, $\frac{2}{20}$ths are required upon the inside strake of shell plating below the sheer strake, and $\frac{2}{20}$ths to the upper deck stringer plate.

It may again be pointed out, that in all vessels of full scantlings, and of

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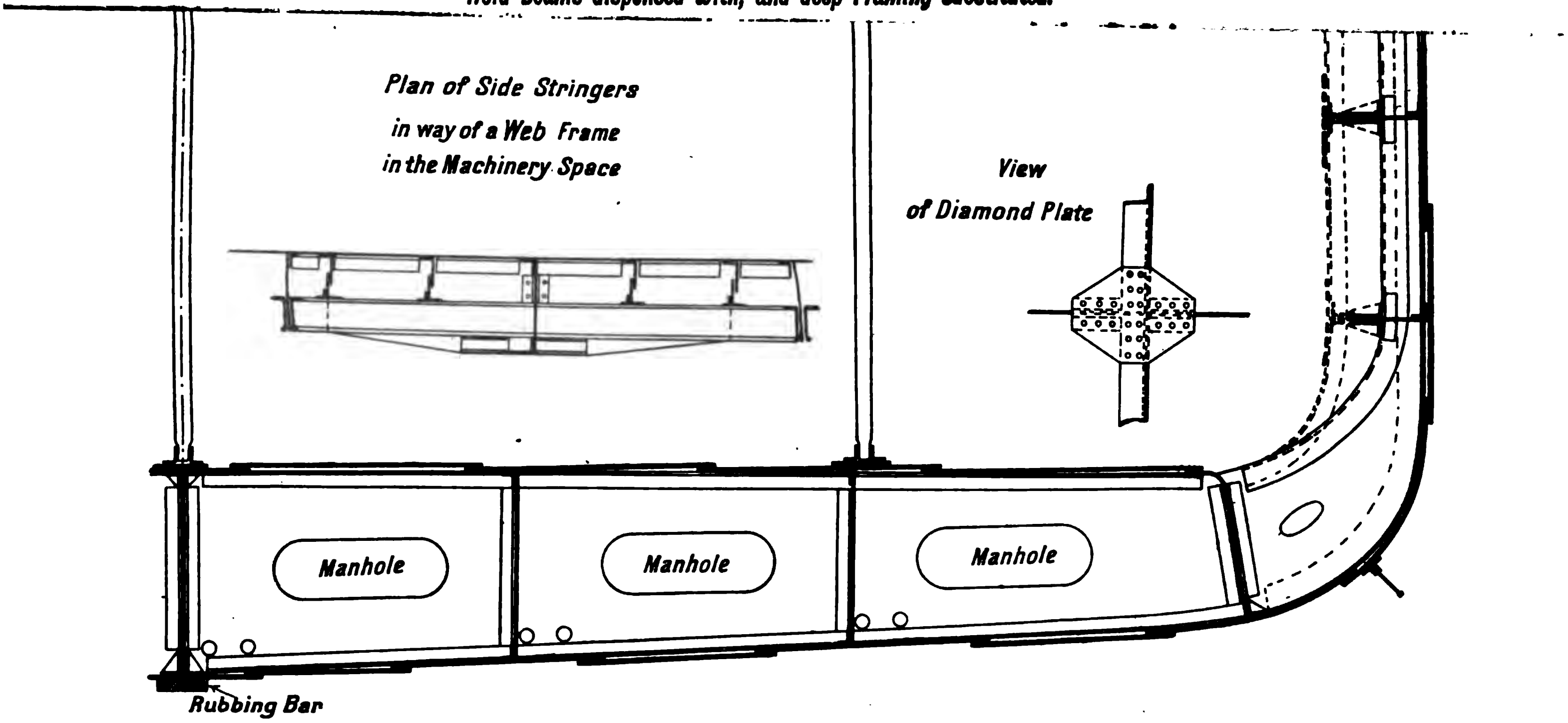
* Or as an alternative and in many respects preferable method of construction, increased depth of framing with lighter side stringers might have been adopted.

FIG. 13.

MIDSHIP SECTION OF A THREE-DECK SHELTER-DECK STEAMER.

(See Profile, Fig. 14.)

Hold Beams dispensed with, and deep Framing substituted.



very extreme proportions (Lloyd's say 13 depths in length), a substantial erection (bridge) should cover the half length amidships.

SPAR DECK VESSELS.

First, of ordinary Rule Requirements.—In spar deck vessels, the uppermost or spar deck is the strength deck, as in the case of "three deck" vessels, and for the same reason. As we have previously pointed out, spar deck vessels are of lighter construction than vessels of the same dimensions built to "three deck" rule.

These vessels require to have three tiers of beams, though, as shown for vessels of full scantlings requiring two and three tiers of beams, the lower tier may be dispensed with, providing that compensation be introduced in lieu of the same.

Though a spar deck vessel may be of the same length and depth to spar deck as for a similar "three deck" vessel, both the 1st and 2nd numerals are considerably less. The reason for this is, that the half-girth and depth are taken to the main or middle deck instead of to the upper deck as in "three deck" vessels, with the result that a much smaller 1st numeral is produced, which, multiplied by the length, gives a smaller 2nd numeral. But the proportion of depth to length is also taken to the main deck, and consequently, these vessels are of greater extreme proportions than the corresponding "three deck" vessel, which may mean considerable additions to structural strength.* However, as it is found that taking the depths to length to the main deck would too severely penalise the spar deck vessel if the rule requirements for additional strength on account of extreme proportion were enforced, while the vessel has in reality the benefit of the depth between the main and spar decks, a deduction of two depths is allowed. And thus a vessel of, say, sixteen depths to main deck in the length, would be considered in taking out her scantlings as though she were only of fourteen depths.

In spar deck vessels, all the bulkheads required by rule extend to the height of the spar deck. The spacing of the frames, and the scantlings of frames, reverse frames, thickness of bulkheads, depths and thickness of floors, size of bar and flat plate keels, stems, stern posts, keelson and stringer angles, constructive material in double bottoms, thickness of shell plating up to and including the main deck sheer strake, main and lower deck beams, are exactly the same as are required for a "two deck" vessel of the same dimensions up to the main deck. In short, the vessel up to the main deck is practically similar in construction to a "two deck" vessel, excepting that, in consequence of having so valuable an erection above the

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* In no case, however, does the structural material in the upper parts of these vessels, and the number and thickness of steel decks, require to be in excess of that specified for the "three deck" vessel of the same dimensions. In the case of the bilge and bottom, extra strength is to be introduced strictly in accordance with the actual proportion of their length to depth to main deck.

main deck, which is not only an indispensable but also an integral part of the ship structure, a reduction of two depths is allowed in the proportion of depths to lengths, as just mentioned, which correspondingly affects the additions for extreme proportions.

All the frames extend to the height of the spar deck stringer plate. The reverse frames should extend to the upper part of the frames and to the top of the angle bar on the main deck stringer alternately. In addition to the spar deck, these vessels must have a complete main deck laid and caulked.

In present-day practice, the beams in spar deck are similar in scantlings to those of "three deck" vessels.

While the plating immediately above the main deck sheer strake in spar deck vessels is less in thickness than the plating below, and thus considerably less than what would be required for a "three deck" vessel between the main and upper decks, it is found to be necessary, in order to provide structural efficiency, to increase the thickness of the topmost strake of side plating (the spar deck sheer strake). Hence we find in Lloyd's Rules that both a width and thickness are specified for the spar deck sheer strake according to the 2nd numeral. In order to exemplify the difference in thickness of the side plating between the main and upper decks in a "three deck" and in a spar deck vessel, it is found on referring to Lloyd's Rules, that where the former is 12, 13, and 14 twentieths in thickness, the latter need only be 9 twentieths.

While the foregoing are the principal features in the construction of ordinary spar deck vessels, it will now be evident that their smaller numerals will in many parts cause a reduction in the scantlings of the material as compared with "three deck" vessels of the same dimensions.

Second, Spar Deck Vessels in excess of Rule Requirements.—By carrying up all the reverse frames to the spar deck, and by introducing additional material in such localities as will undoubtedly increase the structural strength of the ship girder, concessions may be obtained in the matter of freeboard. Such additions to strength might be gradually made so as to ultimately bring the ordinary spar deck vessel through every stage of structural strength, until an equivalent in strength to the "three deck" vessel of full scantlings is produced, and naturally, corresponding allowances in freeboard would be secured; or, in other words, the vessel being now a "three decker," a "three deck" freeboard would be assigned.

The freeboard for a spar deck vessel is measured downward from the spar deck.

The standard height of a spar deck 'tween decks is 7 ft. Should this height be exceeded or be less than the standard, a modification must be made in the freeboard assigned.*

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* In *spar decked* steam vessels requiring not more than one steel deck, the wood "main deck" may be dispensed with, provided the frames and reversed frames be of the sizes required for "three deck" vessels, and all reversed frames be extended to the spar deck. A special freeboard may then be assigned.

AWNING DECK VESSELS.

Structural Features.—In standard awning deck vessels, the main deck is the strength deck, it being assumed that damage to the erection above the main deck would not necessarily endanger the safety of the vessel.

The freeboard for standard awning deck vessels is measured from the main deck downwards.

The 1st and 2nd numerals for awning decked vessels are obtained in the same manner, and are in every way identical with those of a spar decked vessel of the same dimensions to the main deck—the girth and depth being taken to the main deck.

Thus, the frame spacing, the size of frames, reverse frames, thickness of bulkheads, depth and thickness of floors, size of bar and flat plate keels, stem and stern posts, keelson and stringer angles, constructive material in double bottom, thickness of shell plating from keel up to and including the main deck sheer strake, main deck beams, hold beams, are all exactly of the same scantlings as for a spar decked vessel of similar dimensions up to the main deck, excepting that the additions for extreme proportions, as we shall see, will be more excessive than in the spar deck. Indeed, all the afore-mentioned scantlings are identical with what would have been required had the main deck been the upper deck, and the vessel, therefore, a simple "two decker."

Although the awning deck erection, as originally understood, and as taken as the standard for this type in assigning a load line from the Board of Trade Freeboard Tables, is a comparatively light continuous superstructure from stem to stern, erected on the main deck, yet it affords both valuable reserve buoyancy as well as additional strength to the ship girder, and receives full recognition in this respect in the Freeboard Tables.

The standard awning deck erection (Lloyd's 1885 Rules) being a light superstructure of much less structural value than the structure of the standard spar deck vessel above the main deck (though, recently, by requiring thicker side plating, the Board of Trade standard for awning deck vessels has been raised), it follows that vessels of this type depend principally for structural strength upon the material up to the main deck, and, in effect, come to be of more extreme proportions than the spar deck, and vastly more so than the "three-deck" vessel. This fact must therefore be taken into account for standard awning deck vessels, and the main hull strengthened accordingly. This is provided for by taking the ratio of length to depth strictly as obtained, that is, exactly as though the vessel were of "two deck" type, the erection being entirely ignored. Thus, unlike the spar deck vessel, no reduction whatever is permitted in the proportions. Hence, more *additional* strength is introduced into the standard awning deck vessel, than into either a spar or "three deck" vessel of similar external dimensions.

The increased scantlings for standard awning deck side plating just referred to was a very decided improvement in this type, for the original awning deck erection was so light a superstructure that not unfrequently unmistakable signs of weakness in topside plating, awning deck stringer, etc., were developed. Moreover, the very extreme proportions which many of these vessels unavoidably reached, incurred the introduction of an enormous amount of additional material into the structure up to the main deck, in the form of doublings to main deck sheer strake and strake below sheer strake, main deck stringer, etc., until ultimately, with enlarged experience, it was found that such disposition of material in awning deck vessels did not produce the highest results in point of efficiency. It is not surprising, therefore, that a great change has taken place in the **modern awning deck steamer**, which, in construction, is practically identical with what is now known as the "shelter deck" erection. Or, perhaps it would be more correct to state that the structural requirements of the modern shelter deck vessel (having 'tween decks exempt from British tonnage measurement) have correspondingly influenced the structural requirements for modern awning deck vessels, as the freeboard of these latter vessels limits the maximum freeboard allowance for shelter deck vessels. In brief, the modification in construction referred to lies in dispensing with the topside doublings required for the original awning deck vessel, and very materially increasing the thickness of awning deck stringer, side plating above main deck stringer, which includes the fitting of a substantial sheer strake at the awning deck (no special sheer strake was required previously), and, moreover, in addition to the usual steel main deck, a steel or iron awning deck is generally required; while for a "three deck" or spar deck vessel of identical external dimensions only one steel deck may be required. An examination of the comparative scantlings given on pages 40 and 41 will better illustrate the points mentioned.

So that, while it is now extremely uncommon to find building a cargo vessel of the original awning deck standard—though purely passenger steamers are, of course, built to light scantlings which may approximate to the original standard awning deck with a substantial awning deck sheer strake,—it must be clearly understood that the modern type of strong awning deck erection, such, for example, as Lloyd's Registry specify in their rules, is entitled to such a freeboard as her strength in comparison with the standard awning or spar deck vessel would give to her, and not to the ordinary awning deck freeboard as obtained from Table C in the Freeboard Tables. As a matter of fact, the modern awning deck vessel of Lloyd's Rules very much more closely resembles a spar deck vessel in structural strength than a standard awning deck one.

It will thus be seen how impossible it is to accurately judge of the structural worth of a so-called awning or spar deck vessel from the denomination given to it alone. So mixed are these types in the present-day practice of shipbuilding, that to possess full information of their scantlings is absolutely essential in order to assign to them their correct value.

All bulkheads in awning deck vessels extend to the height of the main deck excepting the collision bulkhead, which should reach to the height of the awning deck. All the frames extend to the awning deck stringer plate. All the reverse frames extend to the top of the angle bar which runs continuously along the main deck stringer plate on the inside of the frames.

The beams for the awning deck are less in size than required for a spar deck of the same breadth. For example, under a steel spar deck 40 ft. in breadth, bulb angle beams $7\frac{1}{2} \times 3 \times \frac{10}{20}$ would be required upon every frame, while for an awning deck of similar breadth, bulb angles $6 \times 3 \times \frac{8}{20}$ would be sufficient.

Awning deck vessels must have a complete main deck laid and caulked, and the coamings round all hatches, while of less height, should be built as though the main deck were the weather deck.

The Table on pages 40 and 41 will give some idea of the comparative scantlings of a *modern* "three deck," a spar deck, and an awning deck vessel, as required by Lloyd's Rules.

MODIFICATIONS OF PRINCIPAL TYPES.

Raised Quarter Deck Vessels.—See figs. 12 and 15. A considerable difference exists between an erection called a raised quarter deck, and such erections as complete or partial awning decks, poops, bridges, and forecastles. Indeed, in the truest sense, a raised quarter deck is not an erection, but a *bona-fide* integral part of the ship's hull—the term "erection" being used for purposes of convenience. The raised quarter deck is in reality an increase in the depth of the vessel over part of her length—usually the after portion of length. The average height of a raised quarter deck above the main deck is about 4 ft., though it is sometimes of greater and often of less height. It will scarcely be necessary to say that the raised quarter deck erection is *always* an extension in the depth of the hull of the vessel immediately above the *main* deck, and is never found above spar or awning decks, where it would be practically useless. So valuable is the additional buoyancy provided by a raised quarter deck of standard height, that it receives as much credit in the assignment of the freeboard as would be given to a long poop erection of similar length, substantially closed with a bulkhead at the fore-end, and of at least 7 ft. in height.†

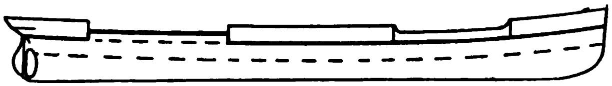

FIG. 15.*—Raised Quarter Deck Vessel.

The standard height for raised quarter decks is—
3 feet for vessels up to 100 feet in length.
4 " " 250 "
6 " " 400 "
Intermediate lengths in proportion.

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* The heavy black lines in figs. 15 to 20 divide the hull proper from the erections.

† When the raised quarter deck is of less than standard height above the main deck, the allowance for freeboard suffers reduction.

Comparison of Construction and Scantlings of a "Three Deck," a Spar Deck, and an Awning Deck Vessel, each of the same Length (inside of Stem and Stern Posts), Moulded Breadth and Moulded Depth to Upper, Spar, and Awning Decks respectively, and Height of 'Tween Decks. 'Tween Decks, 7 ft. Length, 350 ft. Moulded Breadth, 46 ft. Depth from Top of Keel to Beam at Centre (with Normal Round up), 30 ft. Cellular Double Bottom in each case.

"Three Deck" Vessel.		Spar Deck Vessel.		Awning Deck Vessel.	
Length,	350 ft.	Length,	350 ft.	Length,	350 ft.
Breadth, moulded,	46 ,,	Breadth, moulded,	46 ,,	Breadth, moulded,	46 ,,
Depth ,, to upper deck	30 ,,	Depth ,, to spar deck,	30 ,,	Depth ,, to awning deck,	30 ,,
		,, ,, to main deck,	23 ,,	,, ,, to main deck,	23 ,,
Half girth of midship frame,	48 ,,	Half girth of midship frame,	41 ,,	Half girth of midship frame,	41 ,,
,, moulded breadth,	23 ,,	,, moulded breadth,	23 ,,	,, moulded breadth	23 ,,
Depth,	30 ,,	Depth,	23 ,,	Depth,	23 ,,
1st numeral,	94 ,,	1st numeral,	87 ,,	1st numeral,	87 ,,
2nd ,,	32,900 ,,	2nd ,,	30,450 ,,	2nd ,,	30,450 ,,
Depths in length to upper deck,	11·6	Depths in length, 13·2 to main deck (actually 15·2).		Depths in length, 15·2 to main deck.	
Frames, $5\frac{1}{2} \times 3\frac{1}{2} \times \frac{9}{20}$, all to upper deck.		Frames, $5\frac{1}{2} \times 3\frac{1}{2} \times \frac{8}{20}$, all to spar deck.		Frames, $5\frac{1}{2} \times 3\frac{1}{2} \times \frac{8}{20}$, all to awning deck.	
Reverse frames, $4 \times 3\frac{1}{2} \times \frac{9}{20}$, to upper and middle deck alternately.		Reverse frames, $4 \times 3\frac{1}{2} \times \frac{8}{20}$, to spar and main decks alternately.		Reverse frames, $4 \times 3\frac{1}{2} \times \frac{8}{20}$, all to main deck.	
Frame spacing, 24 in.		Frame spacing, 24 in.		Frame spacing, 24 in.	
Or deep framing in lieu of hold beams, $9\frac{1}{2} \times \frac{9}{20}$ in depth.		*Or* deep framing in lieu of hold beams, $9\frac{1}{2} \times \frac{8}{20}$ in depth.		*Or* deep framing in lieu of hold beams, $9\frac{1}{2} \times \frac{8}{20}$ in depth.	
With 3 side stringers, $14 \times \frac{9}{20}$ plate, and single angle $6 \times 4\frac{1}{2} \times \frac{12}{20}$.		With 3 side stringers, $13\frac{1}{2} \times \frac{8}{20}$ plate, and single angle $6 \times 4 \times \frac{12}{20}$.		With 3 side stringers, $13\frac{1}{2} \times \frac{8}{20}$ plate, and single angle $6 \times 4 \times \frac{12}{20}$.	
Bulkheads, lower half, $\frac{7}{20}$; upper, $\frac{6}{20}$.		Bulkheads, lower half, $\frac{7}{20}$; upper, $\frac{6}{20}$.		Bulkheads, lower, $\frac{7}{20}$; upper, $\frac{6}{20}$.	
Pillars (hold), $5\frac{1}{4}$ in. diameter.		Pillars (hold), $5\frac{1}{4}$ in. diameter.		Pillars (hold), $5\frac{1}{4}$ in. diameter.	
Stem bar, $11 \times 2\frac{7}{8}$.		Stem bar, $11 \times 2\frac{5}{8}$.		Stem bar, $11 \times 2\frac{5}{8}$.	
Flat plate keel, $36 \times \frac{17}{20}$, to be doubled for half length amidships.		Flat plate keel, $36 \times \frac{17}{20}$, to be doubled for half length amidships.		Flat plate keel, $36 \times \frac{17}{20}$, to be doubled for half length amidships.	

Stern frame, 11 × $6\frac{3}{4}$.	Stern frame, 11 × $6\frac{1}{2}$.	Stern frame, 11 × $6\frac{1}{2}$.
Garboard strake, 36 × $\frac{18}{20}$.	Garboard strake, 36 × $\frac{17}{20}$.	Garboard strake, 36 × $\frac{16}{20}$.
Upper deck sheer strake, 44 × $\frac{16}{20}$.	Spar deck sheer strake, 40 × $\frac{11}{20}$, doubling for whole width.	Awning deck sheer strake, 42 × $\frac{15}{20}$.
No increase in shell thickness in way of middle deck or tier of beams.	Main deck sheer strake, 44 × $\frac{13}{20}$.	Main deck sheer strake, 44 × $\frac{15}{20}$.
Garboard to sheer strake (upper deck), $\frac{13}{20}$, with an additional $\frac{1}{20}$ on three bilge strakes, and $\frac{2}{20}$ on strake below sheer strake.	Garboard to main deck sheer strake, $\frac{13}{20}$.	Garboard to main deck sheer strake, $\frac{13}{20}$.
	Shell plating between main and spar deck sheer strakes, $\frac{9}{20}$.	Shell plating above main deck, $\frac{11}{20}$.
Upper deck to be of steel, $\frac{8}{20}$ thick for whole length.	Spar deck, steel, $\frac{8}{20}$ thick or whole length.	Awning deck, $\frac{7}{20}$ steel for whole length.
Middle ,, wood, $3\frac{1}{2}$ in. ,, ,,	Main ,, wood $3\frac{1}{2}$ in. ,, ,,	Main deck, steel, $\frac{8}{20}$ thick for whole length.
(Wood middle deck may be omitted if suitable compensation be introduced—see page 33).	(Wood middle deck may be omitted if suitable compensation be introduced—see page 36).	
Upper deck stringer plate, 50 × $\frac{12}{20}$.	Spar deck stringer plate, 50 × $\frac{11}{20}$.	Awning deck stringer plate, 42 × $\frac{11}{20}$.
Middle ,, ,, 72 × $\frac{13}{20}$.	Main ,, ,, 72 × $\frac{10}{20}$.	Main ,, ,, 55 × $\frac{10}{20}$.
Upper deck beams, $8\frac{1}{2}$ × $3\frac{1}{2}$ × $\frac{11}{20}$, bulb angles on every frame.	Spar deck beams, same as "Three Deck."	Awning deck beams, $7\frac{1}{2}$ × 3 × $\frac{10}{20}$, bulb angles on every frame.
Middle deck beams, 12 × $\frac{13}{20}$, bulb plate with $3\frac{1}{2}$ × $3\frac{1}{2}$ × $\frac{10}{20}$ double angles on every 2nd frame.	Main deck beams, same as "Three Deck."	Main deck beams, $9\frac{1}{2}$ × $3\frac{1}{2}$ × $\frac{12}{20}$, bulb angles on every frame.
Centre through plate, 42 × $\frac{10}{20}$.	Centre through plate, 41 × $\frac{10}{20}$.	Same as Spar Deck.
Two side girders, $\frac{9}{20}$.	Two side girders, $\frac{8}{20}$.	,, ,,
Floors on every frame, $\frac{8}{20}$.	Floors on every frame, $\frac{9}{20}$.	,, ,,
Tank margin plate, 33 × $\frac{9}{20}$.	Tank margin plate, 32 × $\frac{9}{20}$.	,, ,,
,, top centre strake, $\frac{10}{20}$; in engine and boiler space, $\frac{10 \text{ and } 11}{20}$; in holds, $\frac{8}{20}$.	,, top centre strake, $\frac{10}{20}$; in engine and boiler space, $\frac{10 \text{ and } 11}{20}$; in holds, $\frac{7 \text{ and } 8}{20}$	,, ,,
Centre girder top angles, 4 × 4 × $\frac{9}{20}$.	Centre girder top angles, 4 × 4 × $\frac{9}{20}$.	,, ,,
Keel plate angles, $4\frac{1}{2}$ × $4\frac{1}{2}$ × $\frac{12}{20}$.	Keel plate angles, 4 × 4 × $\frac{13}{20}$.	,, ,,

Note.—The foregoing scantlings are for steel material extending over the half length amidships. Towards the ends, considerable reduction takes place in the sectional area of both plates and bars.

While it is customary to speak of the raised quarter deck being of a certain height above the main deck, it must be clearly understood that neither decks nor beams are fitted to the main deck immediately under the raised quarter deck excepting for a short distance (a few frame spaces) at the fore termination of the raised quarter deck, or "break," as it is usually termed. What is really done is to interrupt the continuity of the main deck by lifting it up for part of its length to a certain height, and then term the raised part a raised quarter deck. It is therefore constructed exactly as though it were the main deck carried continuously all fore and aft.

The more detail work of obtaining an efficient connection between the main and raised quarter decks is dealt with a little later. It is customary to adopt raised quarter decks in one and "two deck" vessels—seldom in "three deck" vessels, and it may safely be said never when two laid decks are absolutely required. Perhaps the principal reason which led to the wide adoption of the raised quarter deck type of vessel may be given as follows:—

In comparatively small vessels—say up to about 250 ft. in length—it was found that when the engines and boilers were placed amidships, so much hold capacity was lost owing to the space occupied by the shaft tunnel, in combination with the fact that most cargo vessels are designed with the after body somewhat finer than the fore body in order to get a form of hull as consistent with speed requirements as possible, that, when laden with homogeneous cargo, to bring such vessels to a satisfactory trim was practically impossible—the tendency being to trim by the head. By increasing the depth of the hold space abaft of the engines by raising the main deck (constructing a raised quarter deck), this objectionable feature was obviated. Thus, a vessel with a raised quarter deck represents in some degree parts of two separate vessels united into one. The structure of that part without the raised quarter deck is in strict accordance with what would be required for a vessel of the same depth throughout to the main deck. In way of the raised quarter deck, however, all the frames extend to the raised quarter deck stringer plate. The alternate reverse frames extend to the same height, while the intermediate reverse bars are carried to a height such as would be required for a vessel whose 1st numeral was computed by the depth and half girth being taken to the raised quarter deck. The construction of the raised quarter deck, as we have already stated, is a continuation of the main deck. While the number and arrangement of hold beams, beam stringers, and stringers in hold in the part of the vessel uncovered by the raised quarter deck is in accordance with the requirements for the depth taken to the main deck; in the after part of the vessel, which comes in way of the raised quarter deck, these structural items are regulated by the depth which is now increased by the height of the raised quarter deck above the main deck. It will thus be seen that the disposition of the stringers below the raised quarter deck may differ considerably from that in the other part of the vessel.

Indeed, it is possible that the depth, which has now been increased by the height of the raised quarter deck above the main deck, may have actually produced the necessity for an additional tier of beams, or at any rate, additional side stringers. These, of course, must be fitted, unless, in the event of an additional tier of hold beams being required, compensation in the form of deep framing, or web frames, be fitted in lieu thereof.

Now we have previously seen how highly important it is that the continuity of all structural strength should be rigorously maintained. Hence, in vessels of this type, great attention must be bestowed upon the union of that part of the vessel covered by the raised quarter deck and the fore length. This is effected by overlapping the main and raised quarter decks for 2, 3, 4, or 5 frame spaces according to the size of the 2nd numeral and the proportions of the vessel; while in the case of the side stringers, these also are overlapped, or, in some instances, scarphed into one another. The overlapping lengths of the main and raised quarter decks are further blended together by means of a number of fore and aft webs of plating called diaphragm plates.*

In these vessels, the main deck sheer strake is usually carried continuously right aft to the stern, while the side plating above the sheer strake and in way of the raised quarter deck may be $\frac{1}{20}$th of an inch less in thickness than the shell plating below, if such is $\frac{7}{20}$ths of an inch in thickness or more.

As the stresses produced by longitudinal bending moments are always severest wherever any sudden diminution or increase takes place in longitudinal strength, it is very important that special strengthening be introduced at the break, so as to blend, as it were, the strength of the raised quarter deck with its increased depth into the other length of the vessel. Hence it is usual to double part of the topside plating for a reasonable distance before and abaft of the "break." This doubling is usually fitted to the sheer strake, or when the vessel has a bridge house connected to the raised quarter deck, the better method is to double the side plating of the raised quarter deck for a similar distance. In any case, the raised quarter deck side plating must be strengthened in way of the break, and thus, if it is not doubled, it must be increased in thickness, in addition, of course, to the doubling of the sheer strake.

The thickness of the bulwark plating should be increased at the ends of such erections, thus further tending to blend the strength of the one part into that of the other. Great care must be exercised in arranging the butts of the side plating and stringers in way of the break, and ample strength should be introduced into the butt connections, whether they

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* The length of these diaphragm plates is equal to the length of the overlap of the raised quarter deck over the main deck, and the width to the distance between the overlapping decks. The diaphragm plates should be well connected to these two decks by double angles. For such a vessel as illustrated in fig. 12 about four diaphragm plates would be required.

be strapped or overlapped. Usually all the butts are treble riveted in the principal structural parts in way of the break, and the thickness of butt straps increased.

As the break bulkhead is a most vital part in the structure, it is essential that it be of satisfactory thickness (usually same as bridge side plating), well constructed, and connected and stiffened. To this bulkhead the raised quarter deck should be connected by means of double angles.*

Though distinguished by the name "raised quarter deck" vessel, this type belongs to the "full scantling" class, no such erection as a raised quarter deck ever being built, as has already been stated, upon spar or awning deck vessels. They must therefore be considered upon this understanding.

Maximum Stress.—Now, a severe stress for the material in a vessel of the spar or awning deck type is also a severe stress for one of full scantlings. The idea must not be entertained that, because these types differ in their adaptation or efficiency for carrying deadweight, there is any varying degree of maximum stress to which they are respectively capable of being subject, when fully and properly loaded to their properly assigned load lines. Such an idea is erroneous. That is not the manner in which ships are designed and classified. Indeed, the absurdity of such an idea must be obvious after very little thought. The only intelligent and scientific method which can be adopted in considering the deadweight carrying capacity of any vessel is to assign to her such a draught that, when fully loaded with a homogeneous cargo, the material in the structure subject to the greatest stresses—tensional, torsional, and compressive—will be able to endure the same without the possibility of rupture or distortion occurring, and also with no possibility of the material situated in any intermediate locality between the regions of maximum stresses collapsing.

Thus, assuming that a "three deck," a spar deck, and an awning deck vessel were built to rule scantlings, and it were desired that, when each was fully loaded with a homogeneous cargo, not more than 7

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* In order to obtain the *minimum* freeboard for well-deck vessels, it is necessary:—

1. When the crew is berthed in the forecastle, that the "well" between the bridge and the forecastle be bridged by a gangway supported on stanchions (which may be made portable if desired) so as to facilitate the passage of the sailors and firemen to their respective quarters. Where, however, the well is 80 feet or more in length, or the vessel is under 150 feet in length, the gangway just referred to is not required.

2. That the engine and boiler openings be protected and entirely covered by an efficient bridge house.

3. That the total area of the freeing ports in the bulwarks in the well be sufficient to speedily rid the deck of water. This area is determined by the Board of Trade according to the length of the well.

4. That in well deck vessels of the highest class having erections extending over $\frac{7}{10}$ths of their length, the bridge front bulkheads must be specially strengthened and the hatch coamings at least 30 in. high above the deck, while in order to facilitate the getting rid of seas shipped into the well, the freeing port area must be 25 per cent. in excess of that referred to in the foregoing paragraph (3).

tons stress per square inch of material should be experienced on the top of the upper deck sheer strake, it would follow, after the comparison we have made of the scantlings of these respective vessels (see table on pp. 40 and 41), that spar and awning deck vessels must have more freeboard than the "three deck" type, simply because the structural material is less in midship sectional area in spar and awning deck vessels than in the "three deck" vessel. A standard awning deck vessel would have still greater freeboard for the same reason. And with less sectional area of material in the midship sections of vessels of similar depth and breadth, and disposed according to the usual practice for these respective types, the moment of inertia must be less in the spar deck type, and least in the standard awning deck type as compared with the "three deck" type. (See *Steel Ships*, chapter v., "Stress.") And less moment of inertia with equal bending moments must produce greater stress. But this must be obviated of absolute necessity. Hence smaller bending moment is obtained by carrying smaller deadweight, which means less draught or more freeboard, and as a result we have the varying draughts of "three deck," spar deck, and awning deck vessels.

However the design of a vessel may be altered, or whatever peculiarities may be introduced into her construction, she must finally, in receiving her statutory freeboard, come under such test as we have just described, and must satisfy that, with a fully loaded homogeneous cargo of a certain density, she is not unduly stressed, and that she possesses at least the minimum percentage of reserve buoyancy required by the Load Line Act, 1890.

However (as shown in chapter v., *Steel Ships*), there is no such thing as a standard maximum stress for all types and sizes of vessels; for local requirements, especially as seen in small vessels, may demand certain structural strength in order to resist strains apart altogether from those produced by longitudinal bending moments. Hence small vessels, when fully loaded, are rarely stressed beyond 4 or 5 tons per square inch, while large vessels may reach as much as 8 tons and over.

In the Freeboard Tables and Rules fixed by Act of Parliament, and from which all assignments for British Load Line Certificates are made, the three types of vessels we have thus far considered—"full scantling," "spar deck," and "awning deck"—are all that are mentioned for steam vessels. So that to what society's rules a vessel may be constructed and classified, or to what special design she may be built, it matters not. If she is required to have a minimum freeboard, she must belong, from a structural point of view, to one of these three types, or to some modification or intermediate grade between them, and upon the strength so ascertained will she receive her statutory freeboard.

Deck Erections other than Awning and Raised Quarter Decks.—Having noted the character and value of the complete awning deck erection from both a buoyancy and a structural strength point of view, and also the raised quarter deck, which, it may not be unwise to reiterate, is much more than an erection—or it may be still more correct to say that it is not an erection at all, but an integral and vital part of the vessel's hull—we shall briefly examine the structural features and value of other erections which rank of less importance. Vessels having such erections may be described and illustrated as follows:—

1. *Partial Awning Deck Vessels.*—With long raised quarter deck and partial awning deck covering the whole length. See fig. 16.

After the description already given for raised quarter deck and awning deck vessels, little more needs to be said about this type. Such vessels are built to scantlings from numerals obtained by taking the girth and depth up to the main deck, the erections agreeing with the rule requirements for raised quarter decks and awning decks respectively. The part awning deck erection, which, as has been shown, may be of comparatively light construction, is well suited for light cargo, such as cattle or even passengers. It affords protection to the engine and boiler casings, and forms, with the raised quarter deck, a continuous erection providing valuable reserve buoyancy, for which due allowance is made in determining the freeboard. The main and raised quarter decks are scarphed (overlapped) and connected as for vessels with raised quarter decks connected to bridge-houses, except in the very smallest vessels, where a system of knee bracketing is sufficient.*

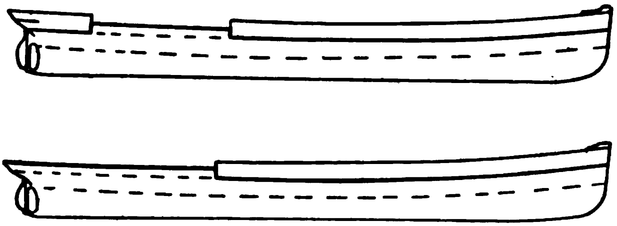

FIG. 16.—Vessel having long raised Quarter Deck and partial Awning Deck together completely covering the whole length (with or without a poop). Known as partial Awning Deckers.

2. *Shelter Decked Vessels.*—See fig. 17.

The great development which has taken place in recent years in the

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* It may be pointed out that the Board of Trade Freeboard Rules allow even a less freeboard in vessels of this type than for standard awning deck vessels, if certain structural conditions are fulfilled whereby the partial awning deck erection is brought up to a state of structural efficiency more in harmony with the strength of the raised quarter deck. It is also assumed that the partial awning deck covers the engine and boiler openings. These structural conditions, the rules state, must be in accordance with the requirements described in section 44 of Lloyd's Rules for the year 1889, and include increased thickness of side plating, stronger stringer plates, a steel or iron deck, and increased riveting in the side plating. Where, however, the partial awning deck is built to standard requirements for awning deck vessels, the allowance for freeboard will be similar to that for a vessel with a complete awning deck.

cattle carrying trade is chiefly responsible for the evolution of the "shelter deck" vessel. This is usually a "three deck" vessel with a complete erection all fore and aft, entirely closed from the sea, with the exception that it is fitted with one or more openings through the shelter deck, which may extend from side to side of the deck, or simply be an opening resembling a hatchway, the coamings of which must not exceed 12 inches in height above the deck, and no permanent means provided for battening down the opening with planks. With such a deck opening or openings, it is evident that, in heavy weather, it is not improbable that, in shipping seas on deck, water may find its way into the 'tween decks between the upper and the shelter decks. Hence, waterports and scuppers are fitted in shelter deck spaces.

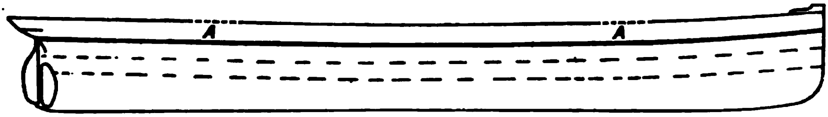

Fig. 17.—Shelter Decked Vessel.

Note.—Dotted lines in Shelter Deck at A denote openings (not hatchways).

A principal reason why this type of erection is generally adopted for the carrying of cattle is that all unenclosed space in a shelter deck 'tween decks is exempted from the gross tonnage of the vessel, while, according to its value in affording reserve buoyancy and strength to the ship as a whole, it receives considerable credit in the assignment of the freeboard.

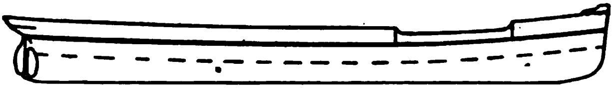

Fig. 18.—Well Deck Vessel, *first type*, long poop and bridge combined and topgallant forecastle.

Well Deck Vessel of second type is that previously described and illustrated in figs. 12 *and* 15.

There are no definite rules for the construction of shelter deck erections. But, with the exception that the shelter deck is an erection upon a "*three deck*" vessel (in arriving at whose first numeral a deduction of 7 is made while no such deduction is made for the awning deck numeral), it is very similar in construction to the *modern* awning deck erection (see page 38). The shelter deck is usually of steel or iron.

Against its value from a strength standpoint there is to be considered the diminished value of the buoyancy of such 'tween decks owing to the openings already mentioned. By fitting complete iron or steel bulkheads to the poop, bridge, and forecastle spaces in the shelter deck 'tween decks, its value as an erection is considerably enhanced.

Well Deck Vessels.—With long poop and bridge combined, and topgallant forecastle. See fig. 18.

The particulars of the principal structural features of such erections may be enumerated as follows:—

(1) All frames extend to poop, bridge, and forecastle decks.

(2) Poop and bridge beams of same size as awning deck beams.

(3) Forecastle beams similar to spar deck beams.

(4) Side plating of same thickness as required for awning deck vessels.

(5) As the forecastle sides are particularly exposed to the full force of the sea, extra stiffness to the plating should be introduced, especially in large vessels. This may be done by carrying up the alternate reverse frames, or by fitting a double angle stringer midway between the forecastle and upper deck.

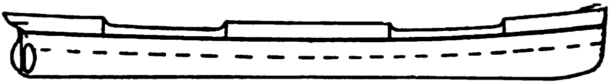

Fig. 19.—Vessel with poop, bridgehouse, and forecastle.

(6) The bulkhead at the fore end of the combined poop and bridge house should be of the same thickness as the side plating—the coamings being $\frac{1}{20}$th of an inch thicker. This bulkhead should be well stiffened vertically with bulb plates and angles or channel bars or any other equivalent, spaced about 30 in. apart. These bulb stiffeners should be thoroughly connected to the coaming plates and the decks between which the bulkhead extends. If these decks are not plated, athwart-ship plates should be fitted to their beams, so that an efficient connection by means of bracket knee plates may be effected. (See fig. 21.)

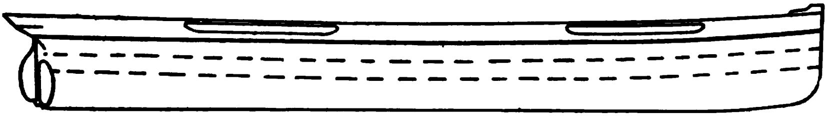

Fig. 20.—Shade Deck Vessel.

The importance of this will be evident when it is remembered that the well between the forecastle and the bridge is especially subject to the incursions of heavy seas, which often dash furiously against the bridge front bulkhead, damage to which might seriously endanger the safety of the vessel should water find its way into the deck openings over the engines and boilers, which are enclosed by comparatively light casings.

(7) Over and above any additional strength which may be required for extreme proportions, *i.e.* over eleven depths to length, necessity for increased topside and local strength exists where a considerable proportion of the length of a vessel is covered by a continuous erection extending two-fifths or more from either end of the vessel in the form of a combined forecastle and bridge, or a combined poop and bridge; or in the case of a vessel having a raised quarter deck, a combined poop and raised quarter deck and

bridge. Thus, in well deck vessels of this type, wherever these conditions exist, local strength to the topsides should be introduced by doubling or increasing the thickness of the sheer strake, increasing the thickness of bridge side plating, bridge stringer plate, and bulwark plating at the fore end of the bridge, and the bulwark rail should be efficiently bracketed to the bridge front. In any case the sheer strake should be doubled for about 20 feet at the fore end of the bridge, and the butt connections should be of exceptional efficiency.

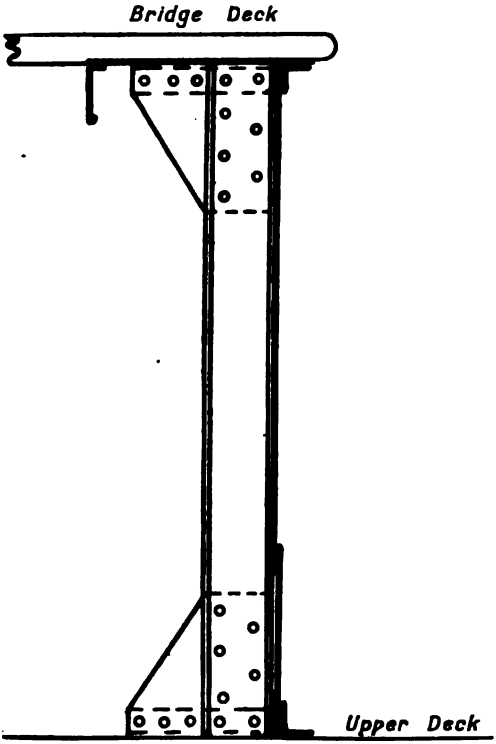

FIG. 21.—Bridge front Bulkhead stiffened with Channel Bars.

Vessel with Poop, Bridge, and Forecastle.—See fig. 19. All the frames extend to the height of the stringer plate on the deck of each of these erections. In neither the poop nor the bridge is it necessary to carry any reverse frames above the upper deck, unless the 'tween deck height of such erections be unusually great, when additional support would necessarily be required. In the case of the forecastle, whose sides are exposed to the full force of head seas, the necessity for ample strength and stiffening is evident. This can be obtained by extending the alternate reverse frames to the forecastle deck, or by fitting a double angle or tee bar stringer along the inside of the frames midway between the two decks. When these stringers meet at the stem bar, they should be connected by means of a plate bracket or breast hook.

While the side plating of poops, bridges, and forecastles is usually comparatively thin, it may be advantageous in certain cases to increase the thickness of the forecastle side plating for the reason just given. A stringer plate is fitted to the ends of the beams on each of these erections.

In determining the load line for vessels of this kind, an allowance is made for the erections strictly in accordance with the value of the buoyancy which they afford. Thus, if the bridge be closed with a thoroughly efficient watertight bulkhead at the fore end, and the after end bulkhead be provided with efficient means for temporarily closing the opening or openings in it, should such exist, and the poop be closed with a bulkhead at its fore end, the allowance will naturally be more than would have been made had these spaces been open at the ends or pierced by alleyways or other permanent openings. The bridge front particularly should have a good coaming plate well connected to the deck, and the stiffeners should be at least as large as the main frames, spaced about 30 in. apart, with bracket connections to the decks at their upper and lower extremities.

Shade Deck Vessels.—The principal function of a shade deck is to afford a shelter and provide a promenade for passengers. As the sides are open, the 'tween-deck space affords no buoyancy, and as the construction is usually of a very light character, because of the light duty it has to perform in the economy of the ship structure, it is practically valueless in contributing to the general structural strength of the vessel. It should, however, be sufficiently strong for the purpose for which it is erected, so as in no way to endanger the lives of the passengers or crew. Such decks may be constructed in a variety of ways; frame angles, tee bars, or round iron stanchions may be used to carry the shade deck beams, while the shade deck itself may be built of light beams with light stringer and tie plates upon which the wood deck is laid (see fig. 20).

In a shade deck vessel, the sides may be open all fore and aft; but when the sides are closed for any part or parts of the length, as in fig. 20, the value of such lengths in affecting the loadline would depend, first, upon the structural character of the vessel below the shade deck 'tween decks, and then, upon the nature of the erections themselves.

Steel Sailing Ships.—Owing to the severity of the transverse stresses experienced by sailing ships, tending to rack and distort the form in that direction, additional transverse strength is introduced into large vessels (1) by carrying the reversed frames up to the gunwale on every frame, (2) by making the beams deeper than would be required for steam vessels of the same size, at any rate to the lower and orlop decks. Special care should be taken in the formation of the beam knees. When the knees are not made of bracket plates, the beam ends should be turned down to form the knees as shown in fig. 97. All beam knees should be three times the depth of the beam. (3) When no steel deck is fitted, there should be, in addition to the fore and aft tie plates, diagonal tie plates laid upon the deck, so as to effectively transmit the severe stresses from the masts and the adjacent beams to the stringer plates.

SECTION II.

Description and Illustration of the Principal Structural Features, etc., of some Noted, and also some New Types of Vessels—"Lusitania" and "Mauretania" (including Launching Particulars)—"Campania" and "Lucania"—Turret Steamers—Trunk Steamers—Self-trimming Steamers (Priestman's)—Cantilever Framed Self-trimming Steamer—Some New Features in Modern Shipbuilding—Typical Steam Collier—Large Single Deck Steamer—Stringerless Type—Oil Steamers—Water-ballast Arrangements.

THE "LUSITANIA" AND "MAURETANIA."

In 1905 the Cunard Steamship Co., Ltd., contracted with Messrs John Brown & Co., Ltd., Clydebank, and Messrs Swan, Hunter, and Wigham Richardson & Co., Ltd., Wallsend-on-Tyne, to build the two Atlantic express steamers, the "Lusitania" and the "Mauretania." The conditions imposed were such as to ensure their surpassing anything the world had ever seen in point of size and speed. Except perhaps in very minor details, the ships are identical. Naturally, for vessels so much in advance of anything previously built, and involving such enormous cost, a huge amount of preliminary inquiry and investigation was necessary, and prolonged experimental model tests were made in the Government Haslar experimental tank.

It was finally decided that the vessels should be propelled by Parsons turbine machinery, and that the dimensions should be as follows:—

Length over all, 787 ft.; length between perpendiculars, 760 ft.; breadth moulded, 88 ft.; depth moulded to shelter deck ("Lusitania"), 60 ft. 4½ ins.; ("Mauretania"), 60 ft. 6 in. to lowest part of sheer. Displacement at 33 ft. 6 in. draught = 38,000 tons. Maximum draught = 37 ft. 6 in. = 45,000 tons displacement. The designed speed, 25 knots per hour.

The "Lusitania" was launched on 7th June 1906, at which date the ship, including launching cradle, weighed 16,500 tons. The "Mauretania" was launched on 20th September 1906, at which date the launching weight was 16,800 tons, including launching cradle.

The Clyde-built vessel was completed and ready for her speed trials in July 1907, and the Tyne-built in September 1907.

The nearest approach to these ships in size and speed is the German Atlantic liner "Kaiser Wilhelm der Zweite." Her principal dimensions are:—

Length over all, 706 ft. 6 in.; length between perpendiculars, 678 ft.; breadth, 72 ft. Displacement on 29 ft. 6 in. draught = 26,500 tons. Speed, 23½ knots.

In 1893 the Cunard Co. broke all previous records by their splendid sister ships, the "Lucania" and "Campania." A comparison of their principal particulars will afford some idea of the gigantic advance in these new vessels. See page 64.

Mr W. J. Luke, naval architect to Messrs John Brown & Co., Ltd., Clydebank, in a paper* read before the Institute of Naval Architects in 1907, gives a description of the construction of the "Lusitania." By his permission, and also the consent of the Cunard Co., many of the following details are obtained from this source. In describing the "Lusitania," it will be understood that, in the main, the same particulars and details apply to her sister ship, the "Mauretania." The midship section, fig. 22, affords a good idea of the general system of construction; but before proceeding to enter more fully into details, it may be of advantage to observe some features of paramount importance. In the first place, these ships are classed with Lloyd's, and built under their survey. It was, moreover, decided that the maximum stress upon the materials of the hull should not exceed about 10 tons per square inch, which calculations were based upon the usually accepted conditions, viz., the ship upon a wave of her own length whose height from trough to crest equalled one-twentieth of the wave length. The calculated maximum bending moment slightly exceeded one million foot tons, and the resultant stress under this condition is a hogging one, bringing the upper works into tension. The corresponding sagging stresses, assuming a wave hollow amidships, amounted to only about one-half of this.†

As is well known, the practice has always been to build mercantile steamers of mild steel having an ultimate tensile strength of from 28 to 32 tons per square inch of sectional area. But to have obtained the required strength in the upper works of these mammoth vessels by employing ordinary mild steel, would have entailed the use of such extremely thick side and shelter deck plating and doublings, as to have involved less efficient riveting, owing to the size of rivets required, and the great total thickness (at least three-ply) to be riveted through. The builders, therefore, determined to use high-tensile steel in these upper parts, having an ultimate tensile strength of from 34 to 38 tons, an increase of 20 per cent. over mild steel—this steel, however, to be able to stand all the usual mechanical tests applied to mild steel. As a consequence of the adoption of high-tensile steel in the parts hereafter enumerated, obviously, it was found permissible to reduce the scantlings of certain parts 10 per cent. from the scantlings required had mild steel been adopted. This contributed in no small degree to more efficient workmanship, owing to lesser thick-

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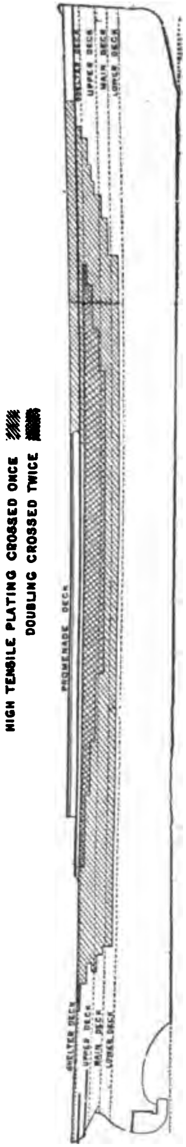
* "On Some Points of Interest in Connection with the Design, Building, and Launching of the 'Lusitania.'"

† The calculated moment of inertia in units of square inches by feet, in round numbers, is 3,410,000, and the bending moment in the condition when entering port, 1,020,000. The consequent stress per square inch on the shelter deck—in extension—is 10·6 tons, and the compressive stress on the keel 7·8 tons.

nesses of plating, and, consequently, smaller rivets being used. More than this, a considerable saving in weight was effected. Fig. 23 is an elevation showing the area covered by high-tensile steel plating on the topsides, and also the extent of the doublings upon such plating. All rivet holes through the high-tensile steel were drilled.



ELEVATION SHEWING EXTENT OF HIGH TENSILE STEEL PLATING ON TOPSIDES

Fig. 23.

Details of Construction.—*Frames.*—The frames above the tank margin plate, and extending continuously to the shelter deck, are formed of channels $10'' \times \frac{20}{40}'' \times 4'' \times 4'' \times \frac{23}{40}''$ for three-fifths length amidships, reduced to 9 in. depth at the ends, *i.e.* the transverse web of the channels is $\frac{20}{40}$ in thickness, and the 4 in. fore and aft flanges $\frac{23}{40}$, which materially increases the moment of inertia (or stiffness) of the frames. The transverse framing is further assisted by broad web frames averaging four frame spaces apart. The frames are spaced 32 in. apart for about 300 ft. of the length amidships to 25 in. apart aft, and 26 in. apart forward, the closing in of the frame spacing being gradually performed.

The Double Bottom.—The floor plates are 60 in. in depth at amidships, and at the tank margin plate they are 48 in. wide. The spacing of the floors is, of course, similar to that of the frames; their thickness is $\frac{10}{20}$ in., excepting under the boiler stools, where they are $\frac{2}{20}$ in. thicker. The frames and reverse frames inside the inner bottom are joggled to avoid the necessity for slip or packing iron. The centre keelson is a continuous longitudinal girder 60 in. in depth, and 1 in. in thickness amidships. All the other fore and aft girders within the double bottom are intercostal between the floors, excepting the fifth one on either side from the centre keelson, *i.e.* E girder, fig. 22, which also is continuous. Consequently, the floors are in one piece from centre keelson to E girder, and from E girder to margin plate. The centre keelson is the only girder within the double bottom, which is watertight. As may be expected, additional longitudinal girders of increased height and stiffness are introduced under the engines.

The outer bottom plating is entitled to special mention. The keel is of the flat plate type, and is made up of three thicknesses (see fig. 22).

The plates making up the keel are at least 32 ft. long, with carefully shifted butts, and the whole is hydraulic riveted. The combined thickness is $3\frac{4}{20}$ in. The inner keel plate is dispensed with beyond the three-fifths length amidships. The garboard inner edge is fitted between the inner and outer keel plates. In order to ensure the most efficient workmanship, only the inner plate forming the keel was punched before being erected in place; the holes in the two outer layers of plating were drilled after being lifted into position. All rag edges were carefully removed by riming before the work of riveting was proceeded with. No butt straps are fitted to keel butts. Practically all the riveting in the bottom plating to the turn of the bilge is done by hydraulic power. This accounts for the apparent narrowness of these bottom strakes, and the fact that, for convenience in hydraulic riveting, the strakes are worked clinker fashion. The garboard strake is $\frac{22}{20}$ in. in thickness at amidships, reduced to $\frac{15}{20}$ in. at ends, while the remaining outer bottom strakes, B to N inclusive, are $\frac{21}{20}$ in., reduced to $\frac{12}{20}$ in. at ends. The riveting in the edges or seams is double, and at the butts double straps are fitted, with double riveting in the outer, and treble in the inner. The inner bottom plating is of necessity hand-riveted. For scantlings, see midship section, fig. 22.

Shell Plating above Bilge.—The length of the shell plates is generally about 12 frame spaces (33 ft.); the edges are treble riveted, while the butts are overlapped and quadruple riveted. Strakes O to T (see midship section, fig. 22) are of mild steel 1 in. in thickness at amidships, and reduced to $\frac{12}{20}$ in. at ends. Strakes U to Y, with their doublings, are all of high-tensile steel. (See midship section for thicknesses; see also fig. 23.) In way of all doublings, the riveting is wrought by hydraulic power. The edges are treble riveted, and the butts of the double strakes are strapped outside and inside at the butts of the outside plates, the outer strap taking three rows of rivets, and the inner straps taking four rows. The butts of the inside strakes are strapped on the inside and quadruple riveted. All rivet holes in the high-tensile steel are drilled, and the holes carefully cleared to ensure the bearing surfaces coming hard up to each other.

Decks and Beams.—There are four complete steel decks laid upon channel beams fitted to every frame. The most important structural deck is the shelter deck. Here the beams are 10 in. in depth by $\frac{20}{40}$ in. in thickness, while the horizontal flanges are each 4 in. by $\frac{23}{40}$ in.; these beams are reduced in scantling towards the ends according to span. The shelter deck stringer and two adjacent strakes of deck plating are of high-tensile steel, and doubled as shown upon the midship section, where thicknesses also are indicated. The remainder of this deck plating is of mild steel. The whole of the deck where doubled is hydraulic riveted.

The upper and main deck beams are exactly similar in scantling to those of the shelter deck. The upper deck stringer and two adjacent strakes are of high-tensile steel; the remainder of the deck is of mild steel $\frac{10}{20}$ in. in thickness. The upper deck stringer is hydraulic riveted. The

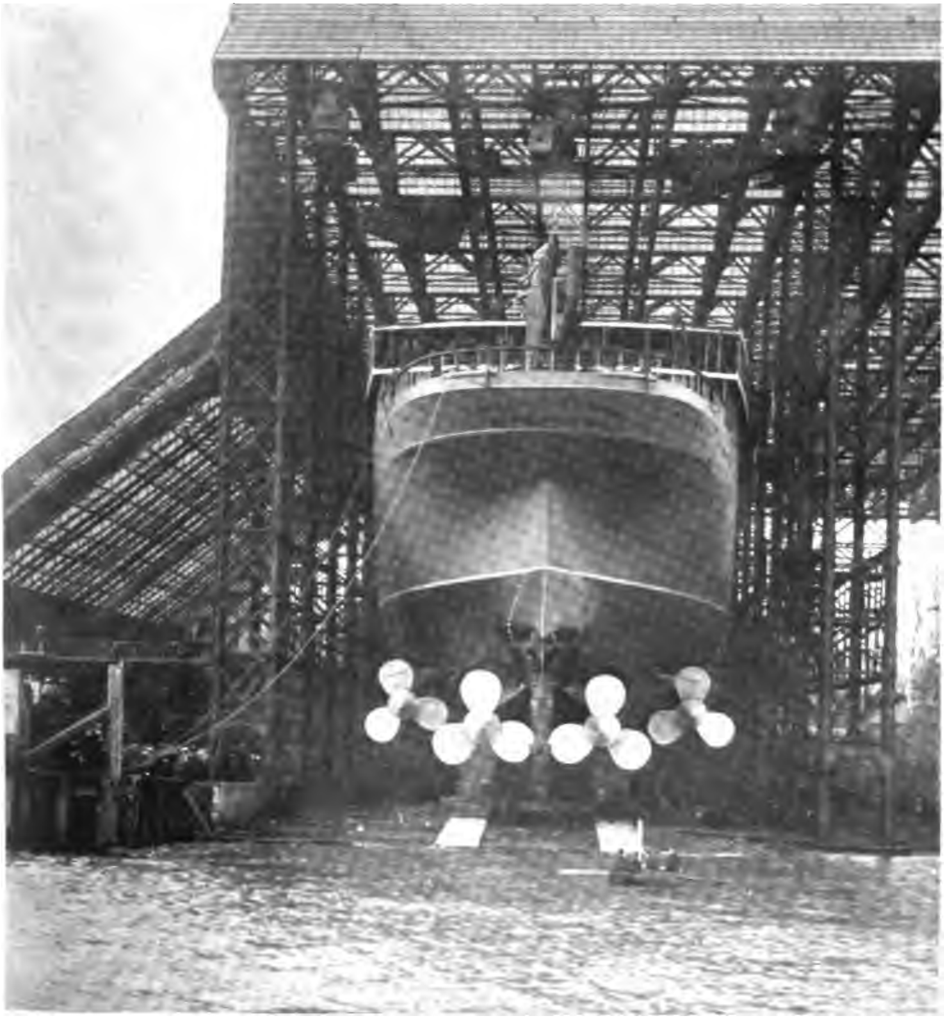
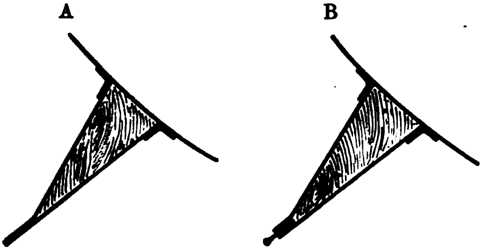


Fig. 23a.—Stern View of "Mauretania" before Launching.

main and lower deck stringers and plating are all of mild steel, while the lower deck beams are of somewhat lighter scantling (see midship section).

Bulkheads.—There are eleven principal watertight bulkheads, built of high-tensile steel, stiffened as indicated upon the midship section. The watertight subdivision of the hull is greatly increased, and the longitudinal strength augmented, by the longitudinal bunker bulkheads which are connected to two engine-room longitudinal bulkheads, forming a continuous fore and aft girder (see midship section).

Stem, Stern Post, etc.—The stem is of cast steel, weighing 8·3 tons, and is rabbeted to receive the shell plating. The stern post also is a steel casting weighing 59·4 tons, specially designed to support the large balanced rudder. The rudder is made up of three steel castings weighing altogether 56·4 tons; the rudder head is of forged steel. All the parts composing the rudder are connected by horizontal flanges well rabbeted and heavily bolted. The rudder area is 420 square feet. The after steering gear is below the designed load line. The spectacles for carrying the four screw shafts are of cast steel, and weigh altogether 60·2 tons. The two after are riveted to the stern post, and the two fore or outer ones secured to the framework of the hull.



FIGS. 24, A and B.—Bilge Keels of "Mauretania" and "Lusitania."

A.—"Mauretania" bilge keel 3 ft. 0 in. in depth from bilge to extremity. Triangular space within bilge keel filled in with wood. Red lead injected between plate and wood.

B.—"Lusitania" same as "Mauretania," excepting that a bulb-plate is fitted at the extremity of the bilge keel.

Bilge Keel.—The bilge keel is of the Admiralty pattern, and projects 3 feet from the bilge; see detail sketch, fig. 24.

Launching Particulars.

The launching of these vessels established a record, not only for dimensions of ship, but for weight of material transferred from the stocks to the water. A very useful and interesting description of the launch of the "Mauretania" is given by Mr H. Bocler, of the staff of Messrs Swan, Hunter, and Wigham Richardson, Ltd., in the spring number of the *Shipbuilder* for 1907. Permission to reproduce the excellent sketches and photographs and the information, was readily granted by the editor. Mr A. G. Hood, for this work. The following particulars, except when otherwise stated, are obtained from this source. Naturally, the fullest

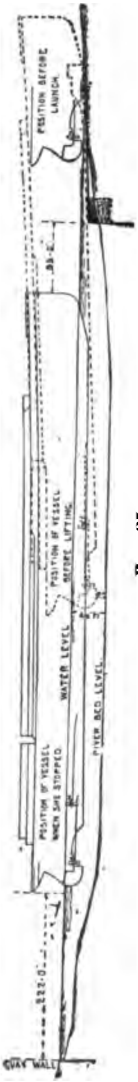


FIG. 25A.

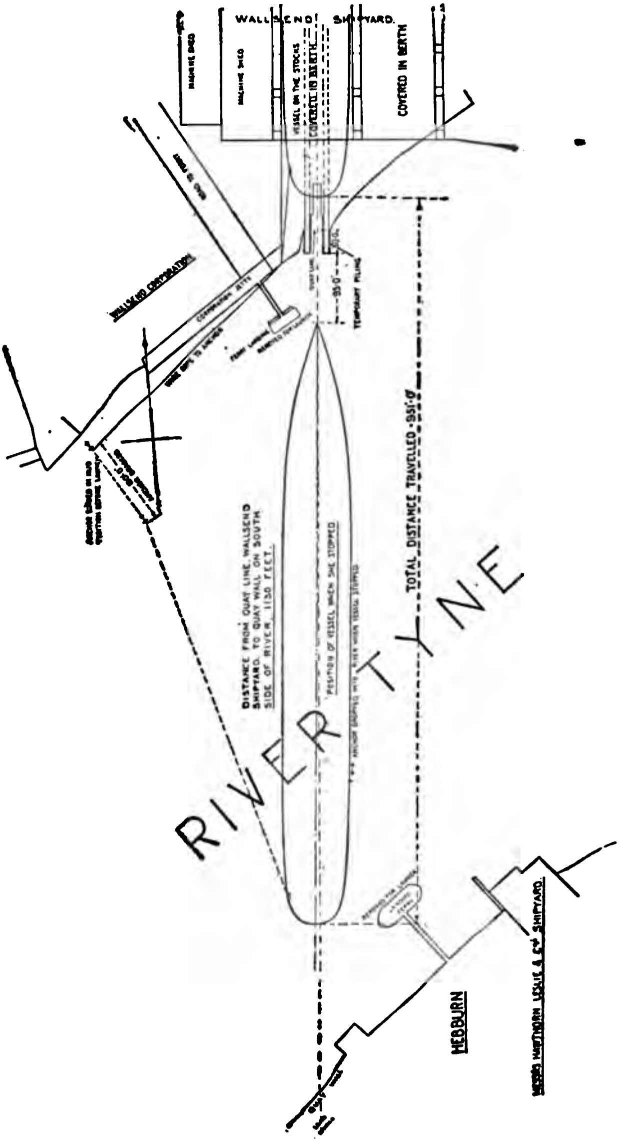


FIG. 25.

and most careful investigation was necessary in the launching of both vessels, for in neither case was the waterway unrestricted in extent. Indeed, the Tyne, opposite the yard of Messrs Swan, Hunter, and Wigham

Richardson, Ltd., is only 785 ft. wide; but three years ago, in order to be prepared to undertake the construction of vessels of the largest size, two berths in this yard were laid out at such an angle to the river, that a clear run of nearly 1200 ft. is available for launching, as shown in fig. 25. Fig. 26 shows the piling of the ground, consisting of 13 in. baulks of timber, driven 30 to 35 ft. into the ground, and upon these piles, every 4 ft. apart, transverse 13 in. baulks are laid for carrying the keel blocks and launching ways.

After making preliminary launching calculations, it was decided to lay the keel with a declivity of ½ in. to the foot, with a minimum height of about 5 ft. 6 in. above the ground. This height was practically constant from aft to amidships, owing to the ground having the same declivity; but forward of amidships, as the declivity of the ground changed to ⅜ in. per foot, it gradually increased to 8 ft. 6 in. at the fore poppet (see fig. 27). The keel blocks were built as shown in

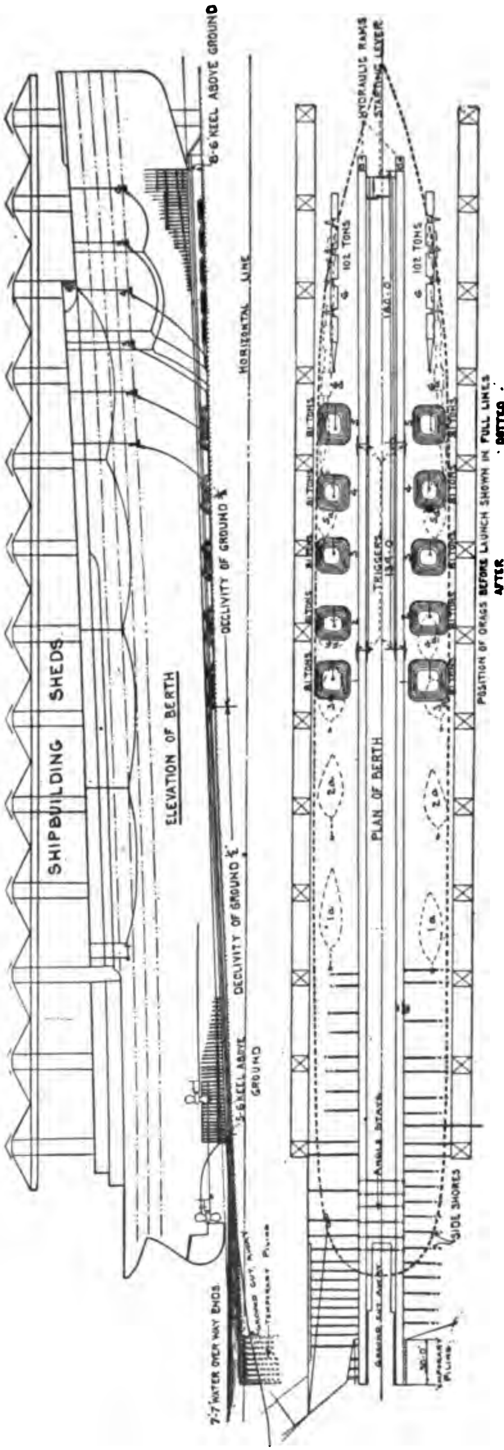


FIG. 27.

Richardson, Ltd., is only 785 ft. wide; but three years ago, in order to be prepared to undertake the construction of vessels of the largest size, two berths in this yard were laid out at such an angle to the river, that a clear run of nearly 1200 ft. is available for launching, as shown in fig. 25. Fig. 26 shows the piling of the ground, consisting of 13 in. baulks of timber, driven 30 to 35 ft. into the ground, and upon these piles, every 4 ft. apart, transverse 13 in. baulks are laid for carrying the keel blocks and launching ways.

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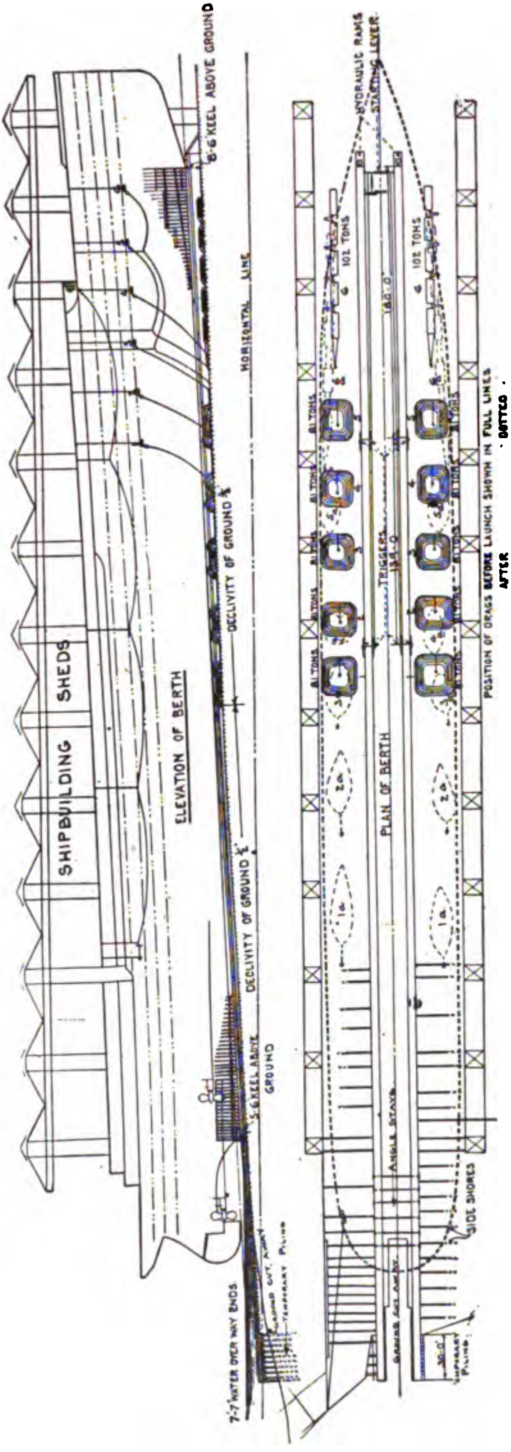


FIG. 27.

fig. 26, B, and were placed in groups of five, about 12 in. apart, with 3 ft. intervals between the groups. The cap blocks were of oak, 12 in. by 8 in. The weight of the ship was further supported while under construction by four rows of shores on each side of the centre line, spaced two frame spaces apart, and by bilge blocks at intervals of about 50 ft.

Before commencing to lay the launching ways, the probable minimum depth of water upon the intended launching day was estimated from the tide tables, and complete calculations made to investigate the effect of differences in the declivity and camber of the launching ways and the extension of the ways into the water, upon the *moment* against *tipping*, the maximum pressure upon the after end of the ways before *lifting*, and the pressure upon the fore poppet when lifting. Guided by these calculations, it was decided to end the cradle 64 ft. aft of the fore perpendicular; and to extend the *ground* or fixed ways 30 ft. beyond the normal quay line, making their length aft of the after perpendicular 98 ft., so that the total length of ground ways was 794 ft. The ground between the ways was cut away, as shown in fig. 27, in order that the vessel's fore foot should not strike the ground when dropping off the ways. The ground ways were laid with a camber of 21 in. in their full length, and a mean declivity of $\frac{9}{16}$ in. per foot. The distance between the top of the ground ways and the bottom of the ship at the closest point forward was about 1 ft. 2 in., and the distance between the top of the ground ways and the ground at the closest point aft was about 1 ft. 1 in. The mean declivity of the sliding ways was slightly over $\frac{17}{32}$ in. per foot at the start. Both the sliding and the ground ways were 6 ft. wide on each side, and spaced 25 ft. apart centre to centre. The sliding ways had a bearing length of 635 ft., so that the bearing surface amounted to 7620 square feet, and the mean initial bearing pressure per square foot on the ways to 2·20 tons.

The distance the ground ways were carried aft of the vessel's stern post was considerably greater than required for providing the usual margin allowed in the *moment* against *tipping*; but this was done in order that the pressure on the after end of the ways and the vessel's floors and bottom before she was waterborne should not be excessive. The curve showing this pressure in fig. 28 has been calculated on the assumptions that the vessel was in equilibrium at any instant and did not deflect, the ways being considered perfectly elastic when compared with the rigidity of the ship; and the values there shown are a fairly correct relative measure of the intensity of pressure when compared with data for other vessels calculated on the same assumptions.

In order to fulfil the condition of equilibrium, the weight of the vessel, W, must be equal to the sum of the buoyancy of the water displaced, D, and the reaction of ways, R, *i.e.*,

$$W = R + D;$$

and the moment of the force D about an axis through the vessel's centre of gravity, G, must equal to that of the force R about the same axis (see fig. 29), *i.e.*,

$$D \times YX = R \times YZ.$$

As the line of action of the force R does not pass through the centre of contact between the sliding and standing ways, the intensity of pressure upon the ways is not uniform, but, with the assumptions mentioned before,

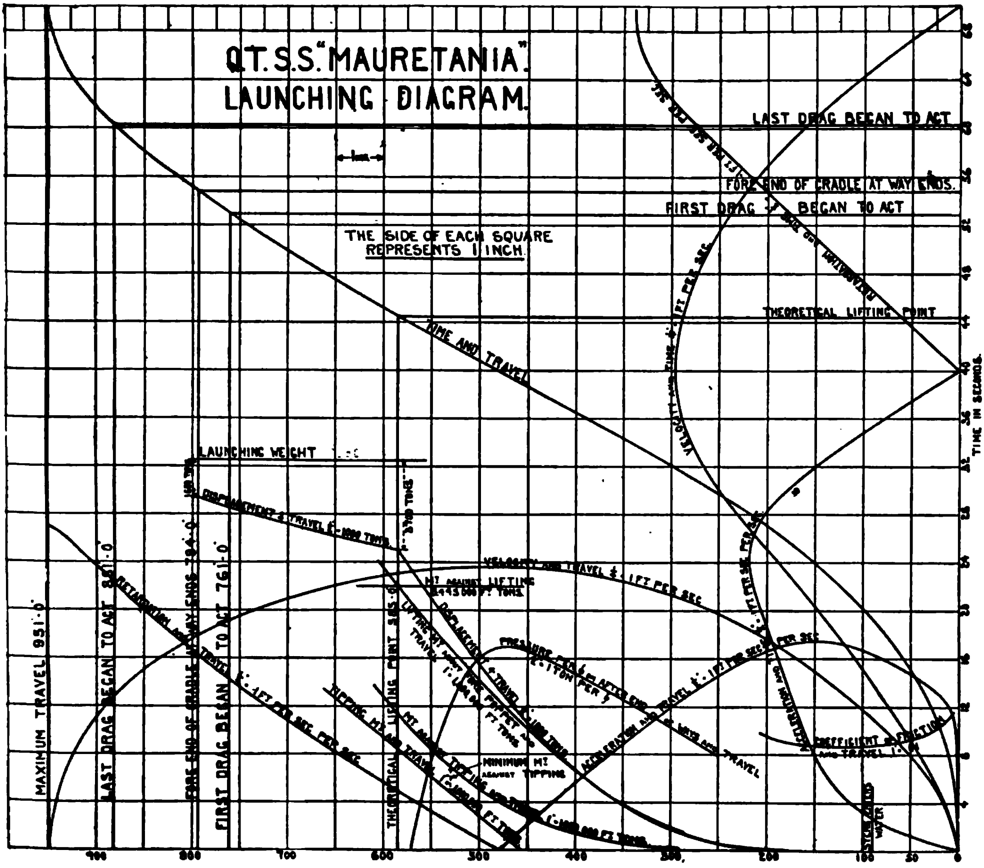
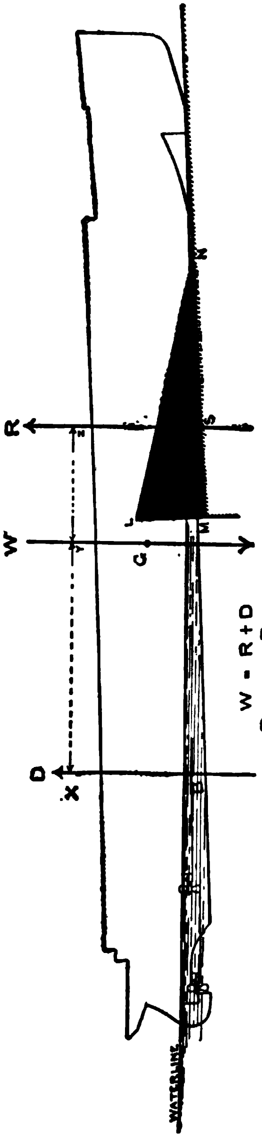


FIG. 28.

varies at a uniform rate and may be represented by a straight line, the diagram of pressure taking the form of a triangle or trapezoid, LMN, as in fig. 29, whose centre of gravity corresponds in longitudinal position with the line of action of R obtained by the equation of moments.

Referring to fig. 28, it will be seen that the minimum moment against tipping was about 420,000 foot tons, and the maximum pressure upon the bottom of the vessel before lifting about 9 tons to the square foot, both occurring when the vessel was about half launched. The floors and tank girders were strong enough to withstand this pressure without the aid of any shoring between the shell and tank top. The greatest draught aft of the vessel before lifting was about 33 ft., and with this there was an ample margin between her keel and the river bed, as may be seen from fig. 25, A.

The ways were of pitch pine, except the forward length of the sliding ways and the after length of the ground ways, which were of oak, and consisted of the usual yard size of way, with extra balks bolted on to make up the 6 ft. of width required, the whole being bolted together by through bolts about 8 ft. apart. Instead of using the usual elm rubber, spiked and bolted to the outer edge of the ways, the outer balk was 2 in. thicker than the others, thus forming a strong guide 2 in. deep, as shown in section of ways in fig. 26, A to D. The average length of the balks forming the ways was about 35 ft., the butts being connected by ½ in. iron straps, with two through bolts at each side of the butt. Two butts on each side were left loose, so that the ways could be removed in three portions after the launch, the necessary ropes for this purpose being connected to eyebolts on the ways. The ground ways were supported against any pressure forcing them outwards at the after end by side shores buried in the ground outside the ways, and by angle stays and brackets between the ways, as may be seen in fig. 27. The after cradle was formed by vertical timbers, held in place by a large angle bar riveted to the shell, as shown very clearly in fig. 30 and in the section in fig. 26, A. The aftermost poppets being slightly inclined inwards, three large balks were carried from side to side to prevent spreading.



$W = R + D$

$D \times YX = R \times YZ$

Fig. 29.

The design of the forward cradle required special consideration on account of the thrust it had to bear when the vessel lifted, which occurred when she had still about 200 ft. to travel on the ways. The estimated value of this thrust equalled about 3700 tons, gradually reducing to 1600 tons when the vessel dropped off the ways. The arrangement of the cradle, which was formed by vertical timbers

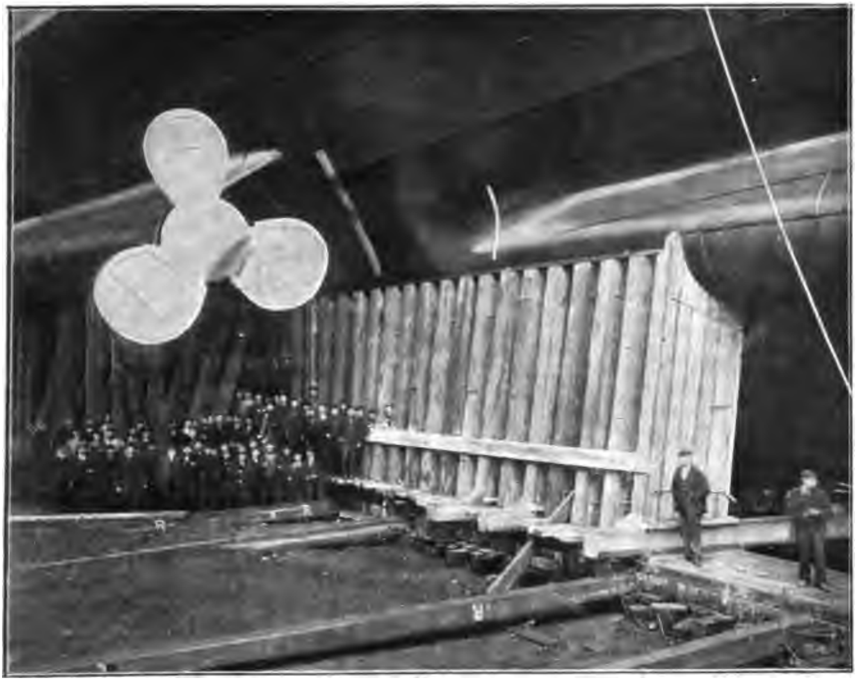


Fig. 30.—After Cradle.

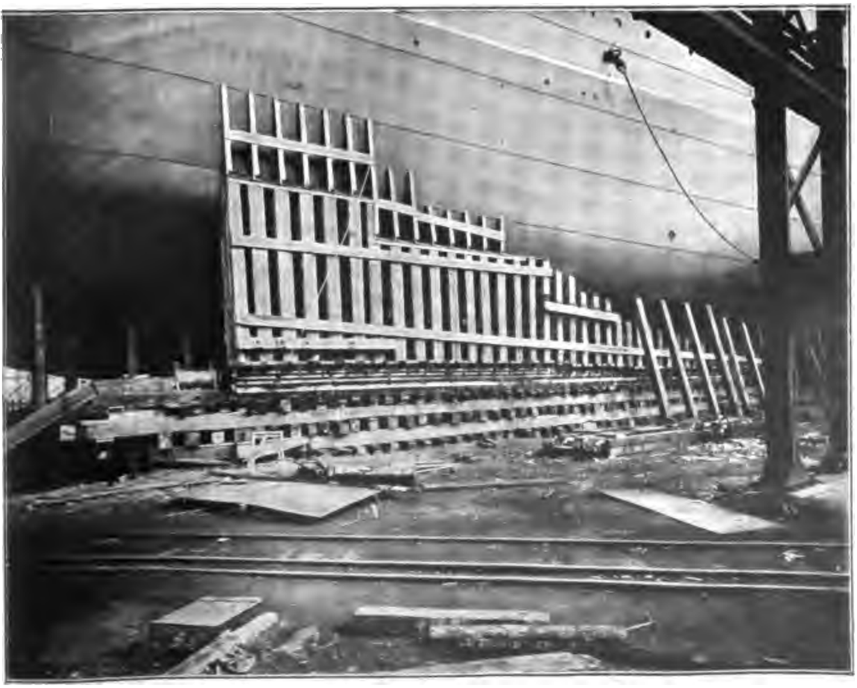


Fig. 31.—Forward Cradle.

with fore and aft ties on the sides, is clearly shown in fig. 31 and in the sections fig. 26, C and D. The only improvement which might be suggested in future cases would be the provision of some extra diagonal ties. Owing to the extreme fineness of the ship, it was necessary to attach a strong shelf plate to the shell, supported by bracket knees, to form a bearing surface for the vertical timbers of the poppet. Even with this arrangement, the foremost timbers were slightly canted inwards. To prevent undue pressure coming upon the lip of the ways owing to the canting of the poppet, four 2 in. tie rods were fitted, as shown in fig. 26, C, with an arrangement of pins, etc., intended to disconnect the two portions of the cradle from each other after the launch. Two shores were also put in on each side from the keel to the lower part of the fore poppets, to prevent the latter canting outwards at the head, in the event of the vessel being slightly slewed by wind and tide before the fore end was waterborne. To facilitate as much as possible the distribution of the thrust over the whole of the shelf plate, a layer of soft timber about 14 in. thick was fitted between the vertical timbers and the sliding ways; but in order that there might be no chance of the brackets giving way, the foremost five on each side, or ten brackets altogether, were made strong enough to stand alone the maximum pressure of 3700 tons, the brackets having double connections to the shell as shown. In addition, four large 3 in. round stays were carried from side to side under the keel (see fig. 26, C), each having a nut on the top of the shelf plate and a bolted palm at the keel. No internal shoring was fitted in way of the poppet, as the framing supported by the stringers and web plates was quite strong enough to bear the thrust, while there were complete bulkheads at the ninth and thirteenth brackets from forward. Aft of the shelf plates, the poppet timbers were held in position by chain lashings, and by narrow plates with angle bars attached, fitting closely against the shell seams, as shown in fig. 26, D. The driving wedges were of red pine about 7 ft. 6 in. long. In way of the vertical timbers at the fore and after poppets, they were double, 9 in. by 3 in. Amidships, only single wedges, 11 in. by 4 in., were used. Ramming up, to take the weight of the ship from the keel and other blocks on to the launching cradle, was commenced the day before the launch.

The lubricant applied to the ways consisted of tallow, train oil, and soft soap, the total quantities used being about 290½ cwt. of tallow, 113 gallons of train oil weighing 12½ cwt., and 22 cwt. of soft soap. Pure tallow was applied first ½ in. thick on the ground ways and somewhat thinner on the sliding ways, then a mixture of tallow and train oil, and finally soft soap in *blobs*. As the total greased area of ground and sliding ways equalled 17,150 square feet, the quantities used per 100 square feet were as follows:—Tallow, 190 lbs.; train oil, 8 lbs.; soft soap, 14½ lbs. The tallow, etc., was put on the sliding ways from underneath by brushes, the ways being alongside their correct positions, so that they could be moved straight into place after coating. The temperature of the atmosphere on the day of the launch was 64° F.

After the keel blocks were knocked out (which occupied about 25 minutes), the vessel was prevented moving by eight triggers placed four abreast, the forward set being 180 ft. aft of the poppet, and the second set 139 ft. further aft, as shown in fig. 27. The design of the releasing gear, which is shown in fig. 32, is similar to that used for all launches at Wallsend, and may be described as follows. When the clip L is pulled back by the rod R, worked from the bow of the vessel, the casting M falls down sideways and the trigger N drops down, leaving the vessel free to move. The rods from each pair of triggers were led to the bow and connected to a crank, which was turned by hydraulic power, as shown in fig. 33, thus releasing all simultaneously. When each trigger moved,

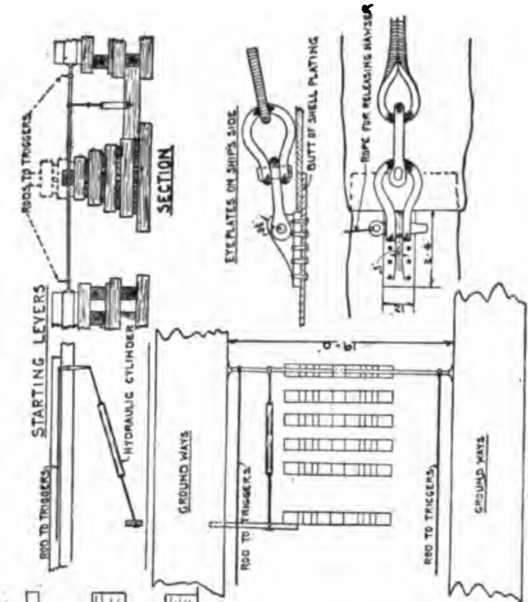


Fig. 34.

Fig. 33.

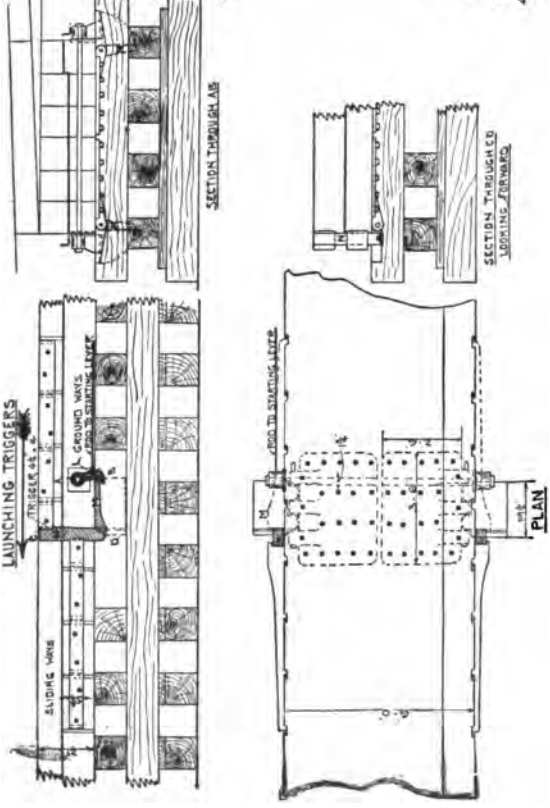


Fig. 32.

an electric connection was broken, putting out an incandescent lamp at the bow to show that all was clear. The vessel commenced to move immediately the triggers were released. In case she had not started promptly, hydraulic rams of 400 tons pressure were fitted at the bow on each ground way, but their use was not required.

To bring the ship up after leaving the ways, six sets of drags were placed on each side, connected to eye-plates on the vessel's shell by 8 in. steel wire hawsers. The eye-plates were fitted against butts of the shell plating to secure additional support, as shown in fig. 34. Ten of these drags consisted of chains, each heap weighing about 80 tons, and two of armour plates (see fig. 27) weighing about 100 tons each, the total weight of the drags being 1015 tons. The chains were laid out in the form of a square, and the connecting strap was carried round the forward portion of the heap, so that the chains had to be pulled over before being drawn out, thus putting on the load gradually. The first drag came into action about 30 ft. before the vessel left the ways, and the last 90 ft. after the vessel left the ways. The position of the drags before and after the launch is shown in fig. 27, the mean distance dragged for the total weight being about 100 ft.

With a view to assist in keeping the vessel's stern up the river as she stopped, a wire rope was led from the after end to an anchor buried in the mud where shown on fig. 25. This rope became taut when the ship left the ways and dragged the anchor 120 ft. This check, however, had practically no turning effect upon the vessel until she had nearly stopped. An anchor was also dropped at the stern to assist in preventing the ship coming back too near the ways and quay. The weather conditions were favourable for the launch, there being only a slight wind on the starboard side of the vessel. The launching speeds were taken by independent observers, with stop watches, timing marks on the vessel, and also by means of a cord unwound from a drum at the bow of the ship. The results obtained agreed very well, and from them the curves of fig. 28 have been plotted. From these it will be seen that the total time from the releasing of the triggers to the time the vessel was pulled up was 70 seconds, and the maximum velocity attained was 23½ ft. per second, or 14 knots an hour. Six tugs were in attendance, and quickly moored the vessel in the position arranged for opposite the yard, thus bringing to a successful conclusion a launch which will always remain memorable in the annals of shipbuilding.

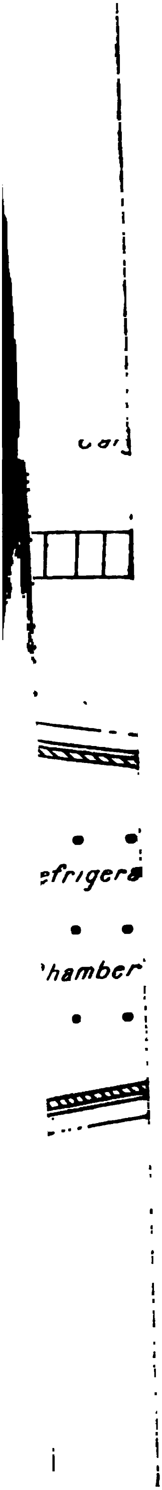
To facilitate reference, a summary of the launching particulars is given in the following table; and where known the particulars of the "Lusitania" are given alongside for comparison:—

Name,	"Mauretania."	"Lusitania."
Length B.P.,	760 ft. 0 in.	760 ft. 0 in.
Breadth, extreme,	88 ,, 0 ,,	88 ,, 0 ,,
Date of launch,	20th Sept. 1906, 4.15 p.m.	7th June 1906
Wind,	Light N.E.	...
Temperature of atmosphere,	64° F.	...

	"Mauretania."	Lusitania."
Draught,	Forward, 11 ft. 7½ in.; aft, 21 ft. 4½ in.; mean, 16 ft. 6 in.	Forward 13 ft. 11 in.; aft, 18 ft. 9 in.; mean, 16 ft. 4 in.
Weight of ship and launching cradle,	16,800 tons	16,500 tons
Centre of gravity of vessel,	27 ft. 0 in. aft of amidships	16 ft. 0 in. aft of midships
Water over way-ends,	7 ft. 7 in.	8 ft. 0 in.
Declivity of keel,	·494 in. per ft. ($\frac{8}{16}$ in.)	$\frac{7}{16}$ in.
Declivity of ways, mean,	·564 ,, ($\frac{9}{16}$,,)	$\frac{51}{100}$,,
Declivity of ways at start,	·545 ,, ($\frac{17}{32}$,,)	...
Camber of ways,	21 in. in 794 ft. 0 in.	16 in. in 795 ft. 6 in.
Standing ways abaft A.P.	98 ,, 0 ,,	84 ,, 6 ,,
Standing ways abaft F.P.,	64 ,, 0 ,,	49 ,, 0 ,,
Sliding ways, total length,	635 ,, 0 ,,	653 ,, 8 ,,
Distance apart of ways, centre to centre,	25 ,, 0 ,,	25 ,, 0 ,,
Width of ways,	6 ,, 0 ,,	6 ,, 0 ,,
Area of bearing surface,	7620 sq. ft.	7844 sq. ft.
Mean initial pressure per sq. ft. of bearing surface,	2·20 tons	2 tons
Maximum pressure on the after end of ways per sq. ft.,	about 9 tons	10 tons
Minimum moment against tipping,	420,000 foot tons	415,000 foot tons
Greatest draught aft before lifting,	33 ft. 0 in.	...
Lifting point from way-ends (statical),	209 ,, 0 ,,	...
Pressure upon fore poppet at lifting point,	3700 tons	...
Pressure upon fore poppet at way ends,	1600 ,,	
Number of drags on each side,	6	8
Total weight of drags,	1015 tons	1000 tons
First drag acted before vessel left ways,	33 ft. 0 in.	...
Sixth drag acted after vessel left ways,	87 ,, 0 ,,	...
Total distance travelled,	951 ,, 0 ,,	...
Bow of vessel from way-ends when she stopped,	93 ,, 0 ,,	110 ft. 0 in.
Total time of launch,	70 secs.	86 secs.
Time for 6 ft. travel from start,	7 ,,	Time for 1 ft. travel from start = 22 secs. The average speed after this was 12·2 ft. per sec.
Time for 794 ft. travel from start,	55 ,,	...
Maximum velocity,	23·6 ft. per sec. = 14 knots per hour	...
Maximum velocity attained after vessel had travelled,	480 ft. 0 in.	...
Maximum acceleration,	·87 ft. per sec. per sec.	...
Maximum acceleration attained after vessel had travelled,	150 ft. 0 in.	...
Mean coefficient of friction for the first 200 ft. of travel,	·0232	...
Vertical fall of vessel's centre of gravity from position on the stocks to position when afloat,	33 ft. 6 in.	...

"CAMPANIA" AND "LUCANIA" (see figs. 35 and 36).

Among Transatlantic liners the twin-screw steamers "Campania" and "Lucania"—sister vessels—belonging, like the two previous vessels, to the Cunard Steamship Co., Ltd., though built in 1893, still hold a front-rank place as fine specimens of naval architecture. They were built by the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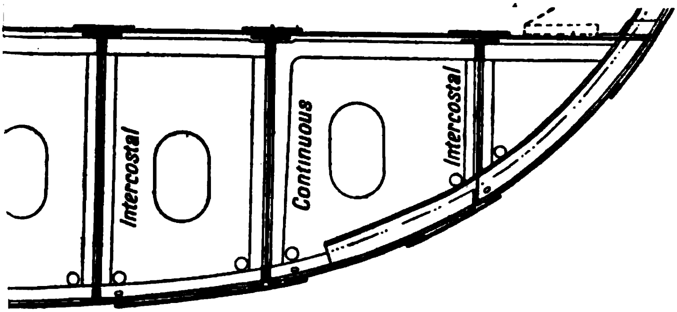
Intercostal
Continuous
Intercostal

Fairfield Shipbuilding and Engineering Co., Ltd., Glasgow (now Messrs John Brown & Co., Ltd.). Particulars of their principal dimensions, etc., are as follows:—

Length over all,	622′ 6″
„ between perpendiculars,	600′ 0″
Breadth extreme,	65′ 3″
Depth moulded to upper deck,	41′ 10″
„ to boat deck,	59′ 6″

About 14 depths in length.

Engines—Twin screw. Ten cylinders.

4 high-pressure cylinders,	37 in. diam.
2 intermediate „	79 „
4 low-pressure „	98 „
Stroke	69 inches.

Boilers—12 double ended, 17′ 6″ diameter × 18′ 9″ long.
1 single „ „ „ 10′ 9″ „
1 donkey boiler, 11′ „ 9′ 3″ „

Natural Draught.

Total number of furnaces, 102.
Working steam pressure, 165 lbs. per square inch.
Indicated horse-power on trial, 31,000.
Speed on trial, 23·18 knots.
Average speed per hour on fastest passage, 22·01 knots.
Gross tonnage = 12,950 tons. Nett register tonnage, 4973.

Passenger accommodation—

First class, 600.
Second class, 400.
Third class, 1000.
Crew, 450.

Most of the structural features are distinctly shown in diagrams 35 and 36, which have been kindly furnished for this work by the owners; hence, more than briefly drawing attention to the chief items in the construction is unnecessary.

The vessels are classed 100 A1 at Lloyd's. They fully comply with the rules of the Bulkhead Committee, in being subdivided into watertight compartments by transverse watertight bulkheads, in such a manner that any two (and in some cases even three) of these compartments may be flooded without endangering the safety of the vessel. The bulkheads are spaced more closely towards the ends of the vessel, where loss of buoyancy would cause most change of trim, and where the danger from collision is greatest The bulkheads are stiffened by deep channel bars, and connected to the tank top and decks by bracket plates. Where passage-ways are required through these bulkheads, watertight doors are fitted, but these are of the least possible number.

Unlike some large passenger steamers, no central longitudinal bulkhead is fitted, excepting through the engine room. Longitudinal bulkheads, apart from structural strength, may be a source of danger to a vessel under some circumstances, for in the event of the shell being perforated and the sea finding access, the loss of buoyancy on the one side only may cause the vessel to take a very considerable list. The necessity for the longitudinal bulkhead through the engine room, however, is so apparent as to need little comment. The two engines driving the two propellers are kept in separate watertight compartments, and thus, in the event of one of them being flooded, the other remains intact, and the vessel has the advantage of propulsion by means of one propeller, at any rate.

The "Campania" and "Lucania" are on the Admiralty list of mercantile armed cruisers, and hence satisfy all requirements for such. Among other features, the boiler compartments are protected against shot at the sides and over the top by watertight coal bunkers. A cellular double bottom extends continuously throughout the whole length. The keel is of the flat plate type, 60 in. broad by over an inch in thickness (see midship section, fig. 36). It has a doubling on the inside of over ⅞ths of an inch in thickness. The double bottom is about 56 in. in depth, excepting under the engines, where it is increased in depth to about 7 ft. 6 in., in order to form the engine seating. The centre through-plate is continuous all fore and aft, with double angles at top and bottom. Between the centre through-plate and the tank margin plate, there is a *continuous* longitudinal girder, also with double angles at the top and bottom. Between this last-mentioned continuous girder and the centre through-plate, and also between the same girder and the margin plate, intercostal girders are fitted as shown in fig. 36. Under the engines, however, where much greater strength and rigidity is required owing to the enormous power of the engines, two continuous and three intercostal girders are fitted on each side as shown in the section of the machinery space, fig. 36. The frames are of channel bar section, spaced 30 in. apart.

In order to give increased stiffness to the transverse framing, there are introduced at intervals, in addition to the numerous transverse bulkheads, deep web frames or partial bulkheads. These web frames are spaced more closely together in the engine and boiler space, where special precautions are obviously necessary.

There are four complete steel decks laid throughout the entire length of the ship, viz., promenade deck, upper deck, main deck, and lower deck, all of which are wood sheathed. The boat and orlop decks have wide stringers and tie plates, and are laid with wood decks. The beams to all the decks are of the butterly tee bulb section, with the exception of those at the end of the promenade deck, which are bulb angle. The promenade deck amidships is supported on T section steel stanchions, which are brought down to the sheer strake, and form stiffeners for the bulwarks (see midship section, fig. 36).

The frames extend continuously from the tank margin plate to the upper deck. The centre through-plate and tank margin plate and some of the side girders being continuous fore and aft, the floors must be intercostal between these longitudinals. At the fore end, where, on account of the high speed, severe panting stresses are encountered, the frames are doubled for a considerable distance abaft of the stem. Doublings are also fitted to the frames for a considerable distance forward of the stern post, where great stiffness is required to carry the propeller brackets, through which severe stresses are transmitted, especially when the vessel travels at high speed. Double angle bar frames are fitted to all watertight bulkheads.

In all steam vessels, owing to interruptions in transverse strength caused by the omission and cutting of beams in the machinery space, too much attention cannot be given to the matter of compensation for such weakening of the structure, and to so strengthening this locality that no signs of weakness may be developed, and vibration reduced to a minimum. It is also necessary to ensure that the foundation upon which the engines and boilers rest is of the most substantial character. In such vessels as the "Campania" and "Lucania," with their enormous engines developing 30,000 indicated horse-power, the strengthening of the machinery space is naturally of the most vital importance, and receives special consideration in the process of designing the structure.

As we have stated, the floors under the engines were increased considerably in depth, and additional longitudinal girders were introduced.

The section through the engine space (fig. 36) well illustrates this. In order that the various parts might be connected in the most efficient manner, all rivet holes in the structure under the engines were rimed and made perfectly true, and the angles in the double bottom were welded and joggled, so as to thoroughly combine the whole and make the transverse framing as continuous as possible.

As the orlop beams had necessarily to be dispensed with in the machinery space, compensation was provided by a semi-box stringer (see section, fig. 36), which is itself furthermore strengthened by the introduction of diaphragm plates at intervals.

The stringer plates on beams are connected to the shell by double intercostal angles instead of by a single angle as commonly adopted.

The shell plating is arranged on the overlap system from the keel to the underside of the main deck sheer strake.

The butts of the upper and main deck sheer strakes, and the strake of shell plating between, are connected by double butt straps quadruple riveted over the middle length and treble riveted at the ends. The straps are placed one inside, and one out. All the other shell butts are overlapped and quadruple riveted over the midship length, and treble riveted before and abaft this. As shown in the section, fig. 36, the upper deck sheer strake and the strake below are doubled over the middle length of the vessel. In long vessels it is a common practice to double one or more strakes of bilge plating, but in the case of the "Campania" and "Lucania" increased strength was obtained by increasing the thickness of the bilge strakes, and adopting treble riveting at the edges or seams of these strakes.

In order to obtain the fullest efficiency, and to ensure the soundest workmanship, hand riveting was dispensed with in the connection of the upper deck sheer strake to the deck stringer plate, as it was practically impossible to obtain satisfactory workmanship by hand riveting so many plates of great thickness (see fig. 36A).

Hydraulic riveting was therefore adopted, and, as a consequence, the rivets are snap-headed. Though the exposed heads of such rivets may be considered by some to detract a little from the general appearance, this consideration was outweighed by the vastly improved character of the work, and the satisfaction felt in having the various thicknesses of plating thoroughly closed up. All rivets are of steel, and in way of the double bottom the riveting is all done by hydraulic machinery. The shell plates range from ¾ in. to 1 in. in thickness.

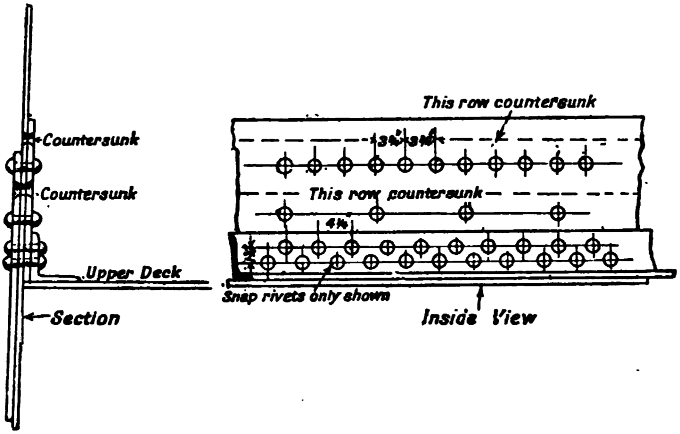

Fig. 36A.—Detail of Hydraulic Riveting in Upper Deck Sheer Strake.

The deck houses are of the composite type, having steel coamings, and frames, and beams (see fig. 145).

The upper deck is sheathed with teak, and the others with yellow pine. The stern frames and propeller brackets are of cast steel.

By adopting the system of bossing the frames at the after end (see figs. 143, 144), not only is thorough support given to the propeller shafts, but ready means of access is obtained to the shafts and their bearings throughout the whole length, excepting the tail shafts.

When the ships were built, they were fitted with plate rudders having specially designed arms on either side. The plates for the rudders were made by Messrs Krupp, of Essen, in Germany, and measured 22′ 0″ × 11′ 6″ × 1¼″ thick. The necessity of going abroad for these plates was afterwards called in question by British makers, and the matter was severely commented upon at the time by some of the leading journals. However, after the ships had run a few voyages, the plates were found to be cracked, and the owners refitted the ships with new cast-steel rudders made up in three sections.

TURRET DECK CARGO STEAMER (see figs. 38 to 47).

This rapidly increasing type of cargo steamer first appeared in about the year 1891, and the very fact that since that time at least 150 of these vessels have been built, some of them reaching to 480 ft. in length, and also that owners who have had vessels of this type built have in many cases given further orders for new vessels of the same kind, proves that "turrets" have shown themselves at least equal, if not preferable, to the ordinary type of cargo steamers for certain trades.

The first turret steamer was designed and built in the shipyard of the patentees, Messrs. Wm. Doxford & Sons, Ltd., Sunderland. Though very different and vastly superior to the notorious whaleback steamer, it is probable that the idea of the turret steamer was first conceived from this vessel. As is now well known, the whaleback steamer was an American invention, and although it was prophesied that this peculiar vessel would revolutionize ship construction, yet the first visit of the first whaleback steamer, the "Charles W. Wetmore," across the Atlantic to this country in 1891 was also her last, and she has had remarkably few successors. Fig. 37 shows the main outline and form of a whaleback steamer. The main object in the design was to provide a sea-going vessel with absolutely clear decks, so that if heavy seas broke aboard, there would be no deck erections to carry away, while the peculiar form of the rounded deck would break the force of the sea, and allow it to easily escape over the sides of the deck.

The great difficulty of getting along such a weather deck in heavy weather is obvious, the only means facilitating this being a gangway above the deck supported upon turrets at intervals in the length.

The hatchways are simply holes in the deck, having no coamings, and closed by means of plates which are bolted through the deck. This is objectionable, as there are no means of feeding the holds when carrying bulk cargoes.

The spoon-shaped bow and the form of the bottom, from the stem for some distance aft, makes the hull specially liable to damage when the vessel is pitching in a seaway, owing to the pounding action produced as the vessel thumps against head seas.

In one or two features, the turret steamer is similar to the whaleback. Neither vessel has any fore and aft sheer, and the gunwale is of rounded form in each case. But beyond these two features they are widely different, as is seen by comparing the diagrams of turret steamers, figs. 38 to 47, with the whaleback steamer, fig. 37.

The following are the principal features in the design and construction of the turret deck steamer.

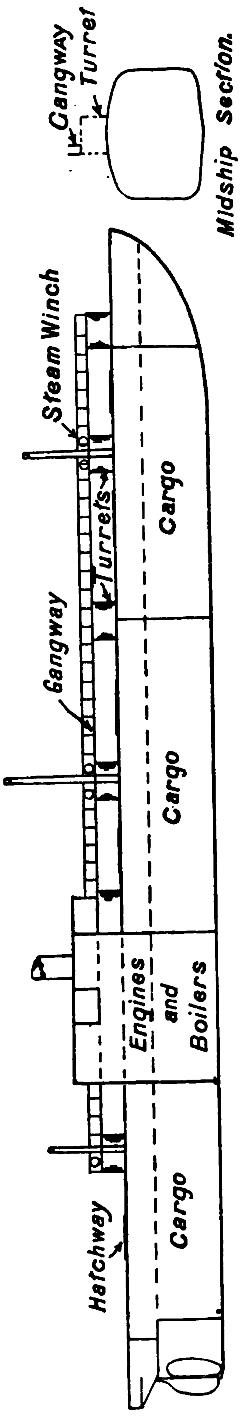

FIG. 37.—Whaleback Steamer.

First of all, it may be noted that the form of the vessel below the load water-line is similar to that of any ordinary steamer, the points of difference being above the load line.

The most striking feature is the turret erection, which extends continuously from stem to stern. The sides of the turret are blended into the harbour deck, and the harbour deck into the vertical side plating, by well-rounded corners (see figs. 39, 40, and 42 to 47).

All hatches (excepting a few small circular bunker trimming scuttles on the harbour deck), deck openings, and deck houses are placed on the turret deck, which at sea is the working deck of the vessel. The harbour deck is practically clear of deck fittings, with the exception of a storm rail for the protection of crew while working mooring bits and fairleaders and watertight coaling ports. As shown in figs. 38 and 41, the accommodation for officers and crew is on the turret; only in special cases, and those chiefly where a large native crew is carried, is any accommodation located in the turret.

As to the strength of these vessels, the very fact that they have been given the highest class by the principal classification societies, leaves no doubt as to their structural merits. Indeed, when the fact is considered that the frames extend continuously from the margin plate of the inner bottom, up the vertical side, round the gunwale and harbour deck, and up the turret side to the turret deck, and also that the thickness of the shell plating is maintained round the gunwale and harbour deck to the turret deck, it is at once apparent that such an erection as the turret, carried continuously all fore and aft, and blended so completely into the main hull of the vessel, must afford a most valuable addition to the longitudinal strength in resisting longitudinal bending. And although the depth of the vessel is increased by the turret erection, yet the transverse form of this upper part, and the assistance given by the thick steel harbour

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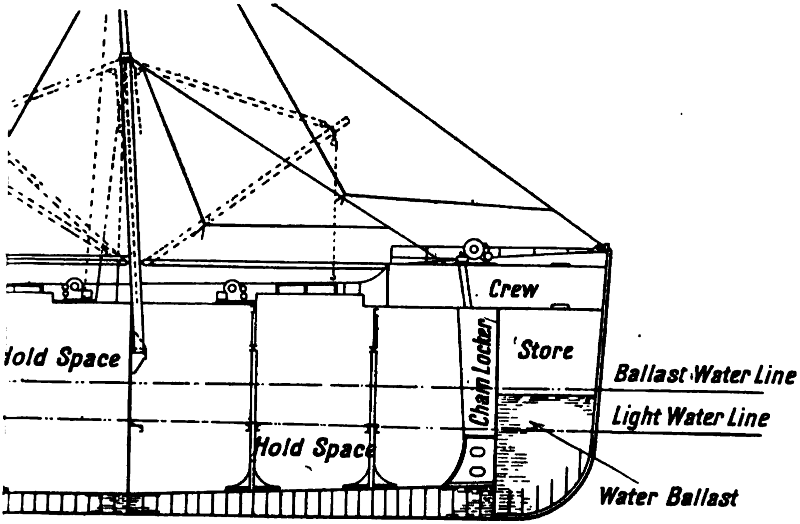
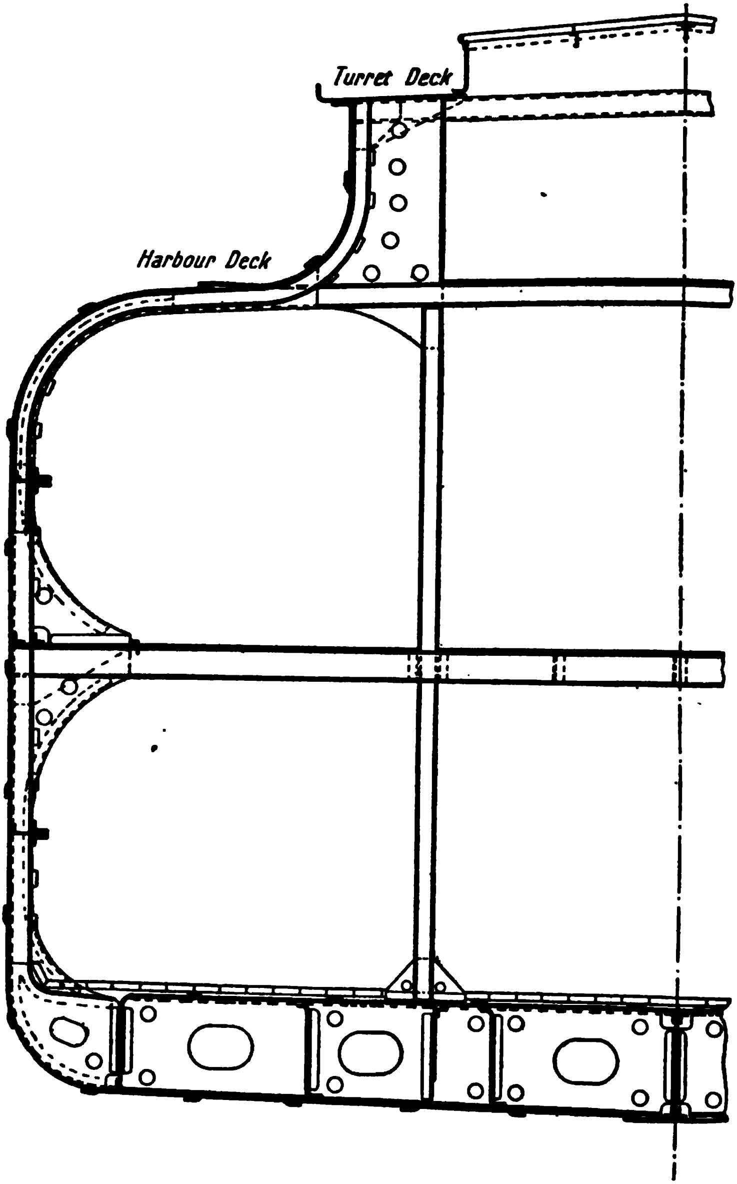


Hold Space
Crew
Store
Chain Locker
Ballast Water Line
Light Water Line
Hold Space
Water Ballast

FIG. 89.

MIDSHIP SECTION OF A TURRET STEAMER WITH ONE DECK AND A TIER OF WIDELY-SPACED HOLD BEAMS.



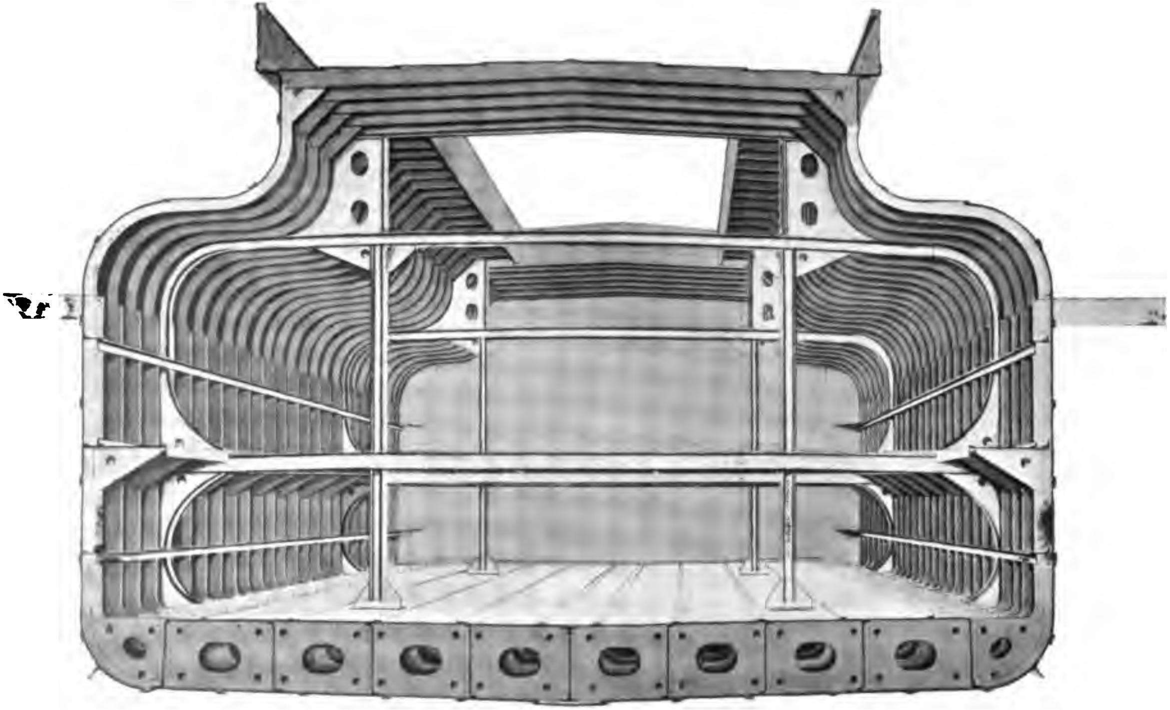


FIG. 40.—Hold View of Turret Steamer. Ordinary method of construction with beams.
Dimensions, 350 ft. 0 in. B.P. × 50 ft. 0 in. moulded × 25 ft. 3 in. depth moulded (harbour deck).

PLATE III.]

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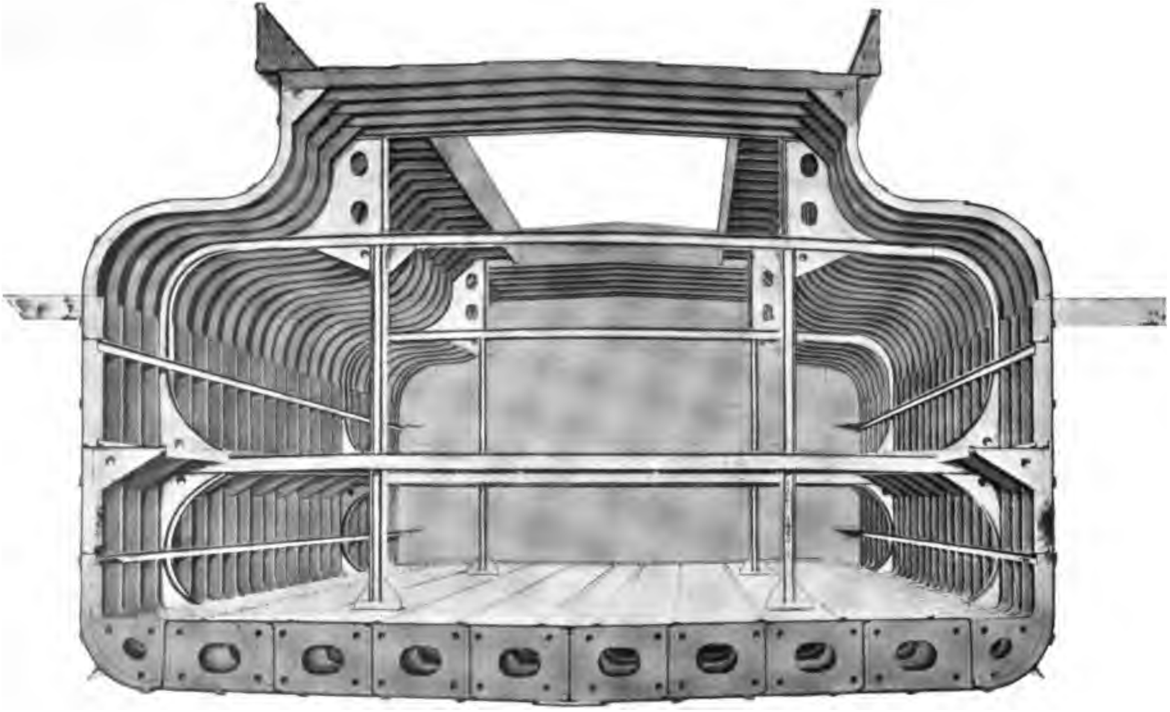

FIG. 40.—Hold View of Turret Steamer. Ordinary method of construction with beams.
Dimensions, 350 ft. 0 in. B.P. × 50 ft. 0 in. moulded × 25 ft. 3 in. depth moulded (harbour deck).


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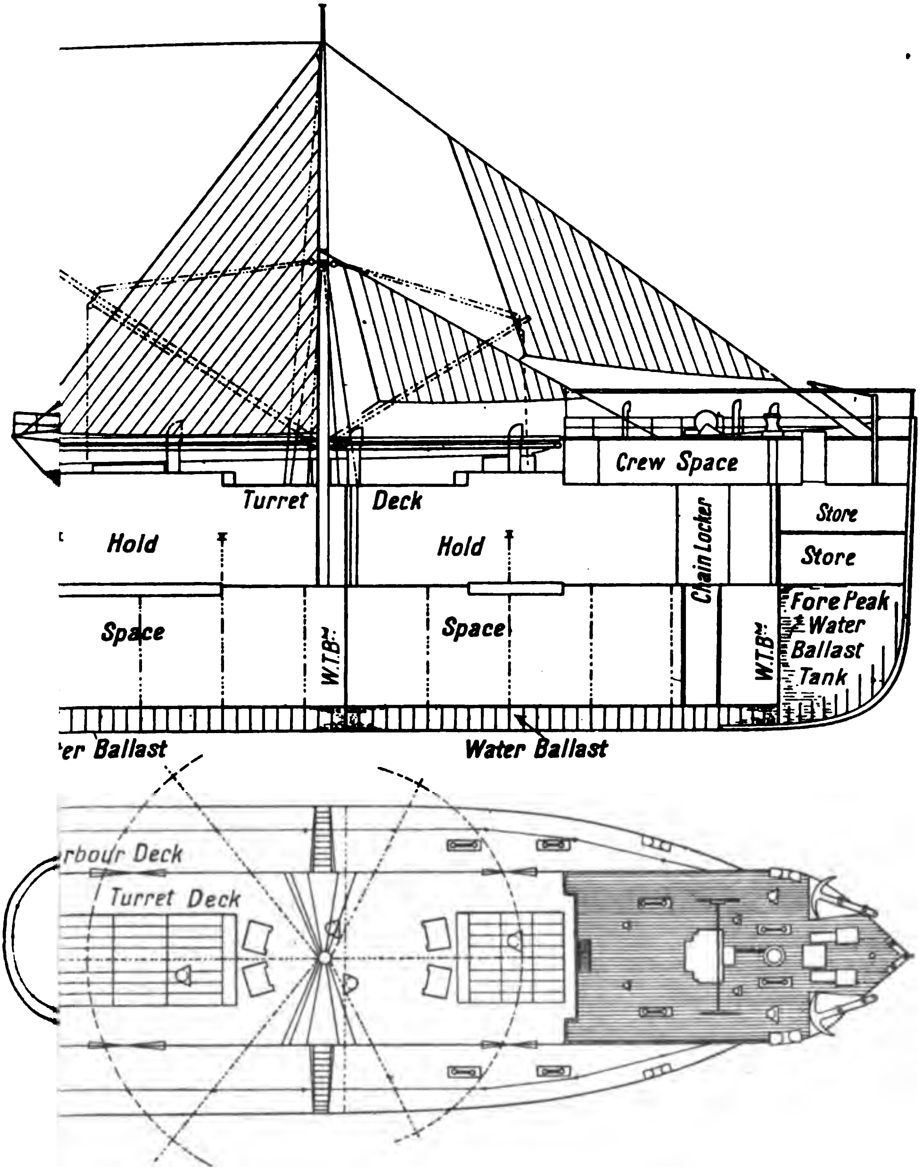

Crew Space
Turret
Deck
Hold
Hold
Store
Store
Chain Locker
Space
Space
W.T.Bᵈ
W.T.Bᵈ
Fore Peak
Water
Ballast
Tank
ꞌer Ballast
Water Ballast
rbour Deck
Turret Deck

FIG. 42.

MIDSHIP SECTION OF TURRET STEAMER WITH TWO DECKS.

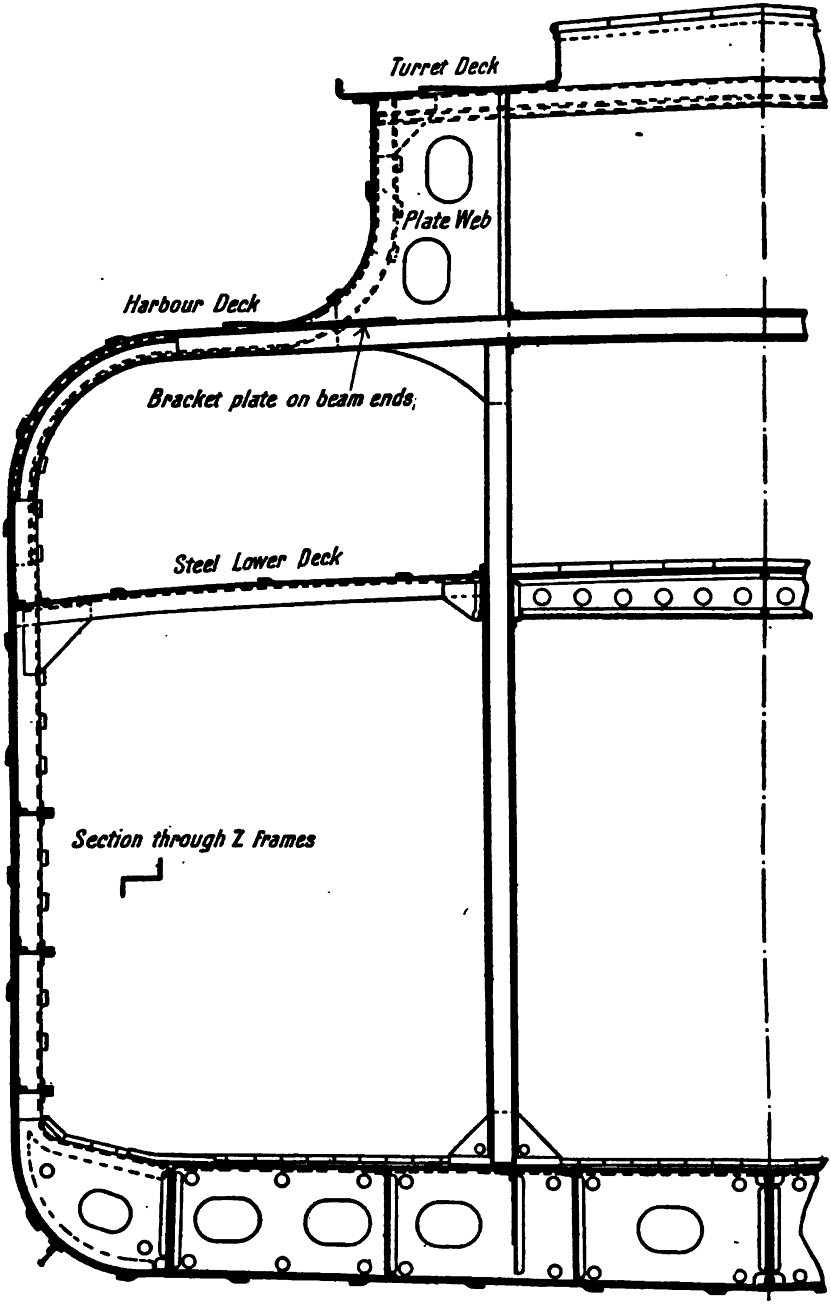

PLATE VI.]

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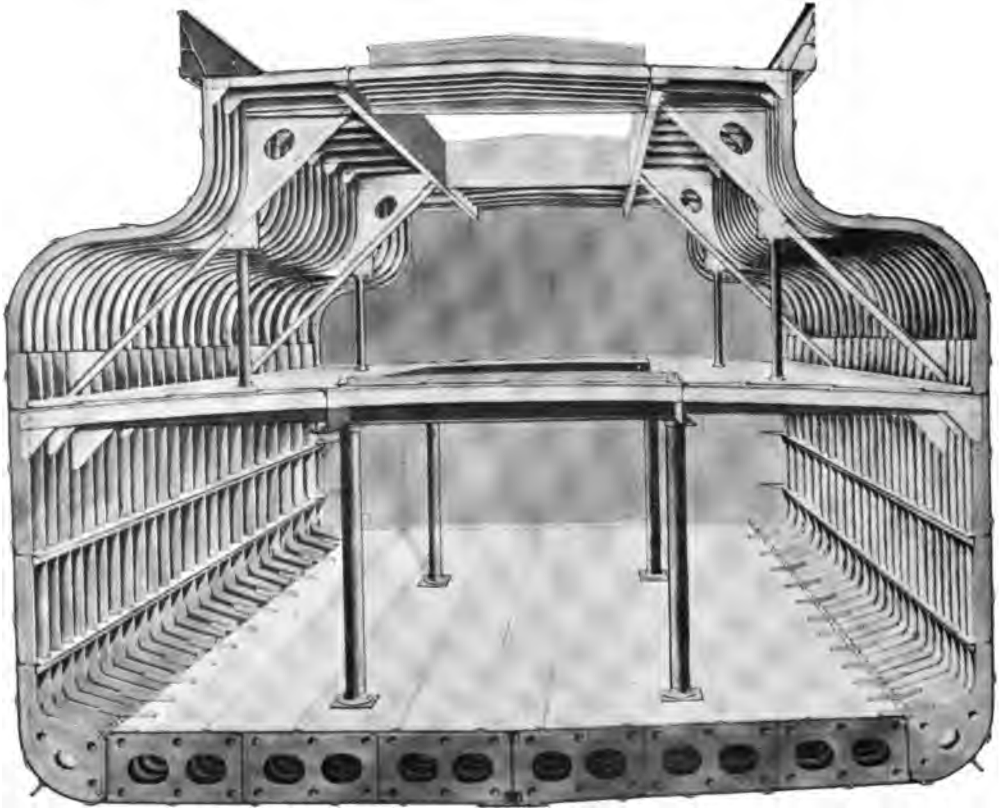


FIG. 43.—Hold View of a 'Tween Deck Turret Steamer. (Widely-spaced steel tube pillars.)
Dimensions, 400 ft. 0 in. B.P. × 52 ft. 0 in. moulded × 30 ft. 0 in. depth moulded (harbour deck).

deck (which in ordinary vessels is usually of thinner plating) and the plate brackets in the turret, between the turret deck and harbour deck beams in figs. 39, 40, and 42, or the equivalent methods in the other midship sections, figs. 43 to 47, prevent any chance of transverse weakness in the topsides. The turret sides and harbour deck really form a pair of huge angle girders, one on each side, extending all fore and aft.

Owing to the increased stiffness which the curved sides give to the deck, and the strength afforded by the large angle girders just referred to, it is quite admissible that the hold pillars, if of increased strength, should be more widely spaced than is usual in ordinary vessels (see figs. 38 and 39). The advantage thus given for better stowage is evident. These pillars were usually made of two channel bars riveted back to back, and bracketed at their upper and lower extremities to the deck beams and inner bottom plating (see figs. 39, 40, and 42); but in later types, steel tube pillars, which are less liable to damage cargo, have been adopted (see figs. 43, 45, and 47).

The turret erection being of a thoroughly substantial character, it is needless to say, in making the strength calculation, that the sectional area of all continuous longitudinal material up to the turret deck is used in arriving at the moment of inertia; hence, with an increased depth of girder, the resulting large moment of inertia is accounted for. At the same time, there being no sheer, and, consequently, relatively less hold space towards the ends of the vessel, a reduction in bending moment would be the result, were there no turret erection suitable for carrying cargo. Any actual reduction, therefore, in bending moment, as compared with an ordinary vessel, may be ignored, but, with increased moment of inertia, it follows that a reduction in the stress per square inch on the topsides may result.

These vessels are usually built with a cellular double bottom all fore and aft, which is of the ordinary construction. The frames are generally of channel or Z section up to the lower round of the harbour deck. Above this height and up to the turret deck the frames are of slightly lighter scantlings and of bulb angle section. These upper and lower frames are efficiently united by an overlap of 27 to 30 inches.

Hold and Harbour Deck Beams and Pillars dispensed with.—The evolution of the Turret proceeds apace, for, as figs. 43 to 47 show, great improvements have recently been made in their internal construction. Many of the latest of these vessels, reaching 30 ft. depth of hold to turret deck, have been built without either hold beams, harbour deck beams, or pillars, thereby leaving an entirely clear hold space (see fig. 44). This is effected by the compensation afforded by the very broad web frames of cantilever form, fitted at widely spaced intervals, in conjunction with a broad web stringer. These vertical webs extend from bilge and tank top, to which they are efficiently bracketed, up to the harbour deck, and from thence, by taking an oblique direction, to the turret deck as shown.

By this system of octagonal web framing, the thrust from the water pressures upon the bottom and side plating respectively is transmitted and distributed over the harbour deck, turret sides, and turret deck—the frame heads just above the load-line being supported by the diagonal web framing which is connected to the turret deck beams. The side support afforded by the hold beams with their broad stringer plate in figs. 39 and 40 is obtained, in the case we are considering (fig. 44), from the broad stringer, held to its work at intervals by the transverse webs. In heavy weather, it is obvious that large volumes of water must find their way on to the harbour deck at the sides of the turret erection. The harbour deck under such conditions is upheld with its load by the cantilevers which the octagonal webs form as they reach out diagonally from the frame heads to the turret deck beams. The clear hold thus obtained is plainly of immense advantage in the stowage of large bales and case cargoes.

Hold and Harbour Deck Beams dispensed with; Widely-spaced Tubular Pillars introduced.—Fig. 45 shows a similar vessel to fig. 44, also with both hold and harbour deck beams dispensed with, the topside support and transverse rigidity in this case being obtained by oblique stays at intervals, composed of two deep channel bars securely bracketed to two adjacent frame heads at their lower extremity, and to the hatch end coaming plate and an adjacent deep plate beam at the upper extremity. These double channel bars are combined into one efficient stout tie by binding plates or straps at intervals in their length, as shown. Support is afforded, immediately beneath the turret sides, by steel tube pillars bracketed to the turret base and sides. These pillars again transmit and distribute the enormous thrust from the bottom pressures. In lieu of the hold beams with their broad stringer plate, the Z framing is increased in depth and thickness. This increased depth of framing makes each frame capable of withstanding the external pressures without the assistance of the deep side stringer.

Special 'Tween Deck Arrangement.—Fig. 43 shows a special arrangement in which a 'tween decks is fitted. The lower deck is supported by widely-spaced tubular pillars in each hold, the feet of these large pillars, in all cases, being secured by tap rivets to a thick doubling plate riveted to the inner bottom, which method prevents any possibility of water finding its way inside the pillars; and the heads are connected to a continuous fore and aft girder on each side, which, in its turn, is secured to deck and beams. These girders also form the hatch fore and aft coamings. Above the lower deck there are no beams until the turret deck is reached, the omission of the harbour deck beams being compensated for by oblique channel bar struts and ties, with large brackets at their extremities. Smaller steel tubular pillars support the turret sides in way of each of these oblique struts.

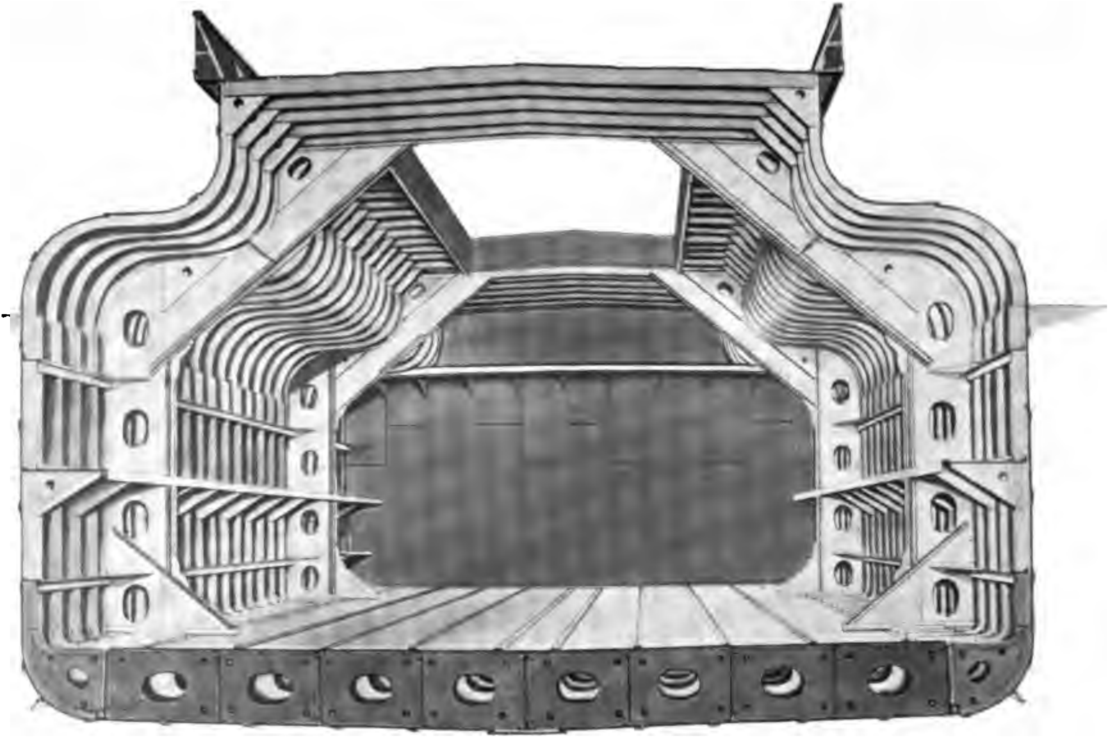


FIG. 44.—Hold View of Turret Steamer having no Hold Beams, Harbour Deck Beams, nor Pillars. Dimensions, 350 ft. 0 in. B.P. × 50 ft. 0 in. moulded × 25 ft. 3 in. depth moulded (harbour deck).

PLATE V.]

[To face page 72.

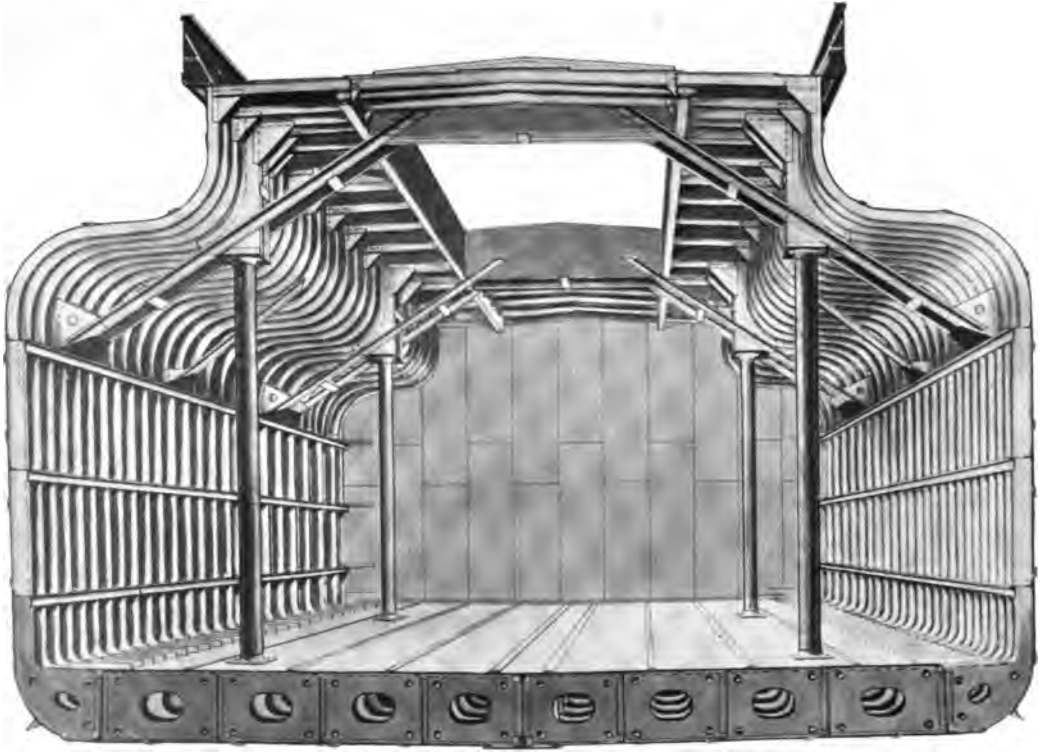


Fig 45.—Hold View of Turret Steamer with widely-spaced Steel Tube Pillars, having no Hold Beams nor Harbour Deck Beams. Dimensions, 350 ft. 0 in. B.P. × 49 ft. 0 in. moulded × 26 ft. 6 in. depth moulded (harbour deck).

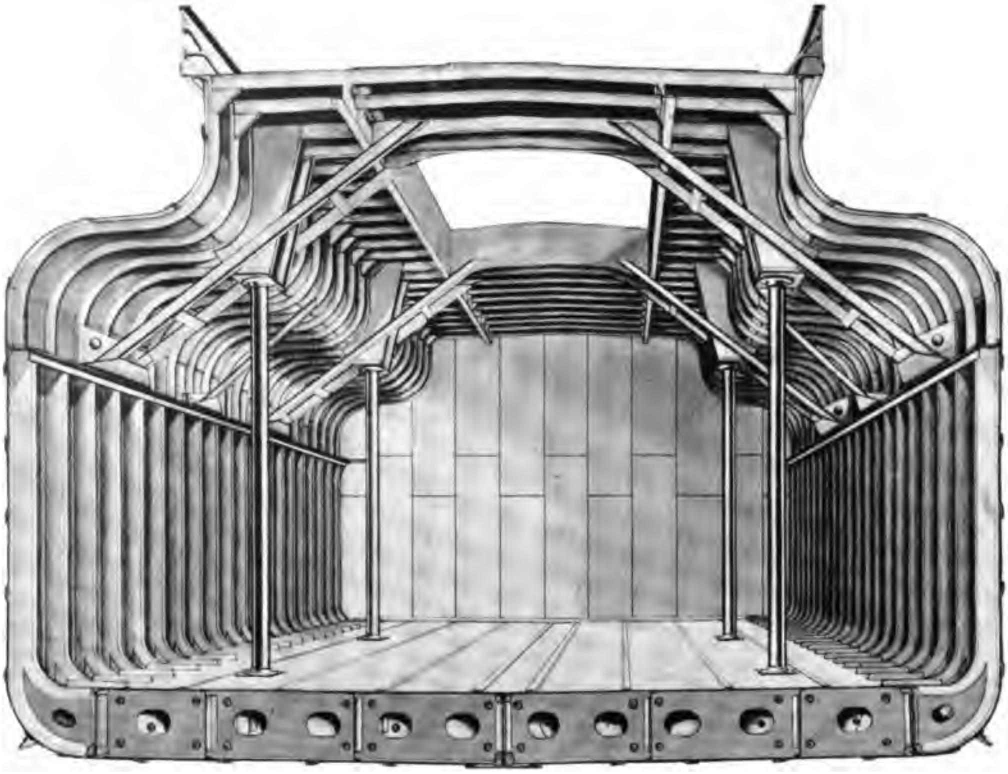


Fig. 46.—Hold View of Turret Steamer with widely-spaced Steel Tube Pillars, having no Hold Beams, Harbour Deck Beams, or Side Stringers below lower Frame Heads.

Dimensions, 350 ft. 0 in. B.P. × 49 ft. 0 in. moulded × 25 ft. 6 in. depth moulded (harbour deck).

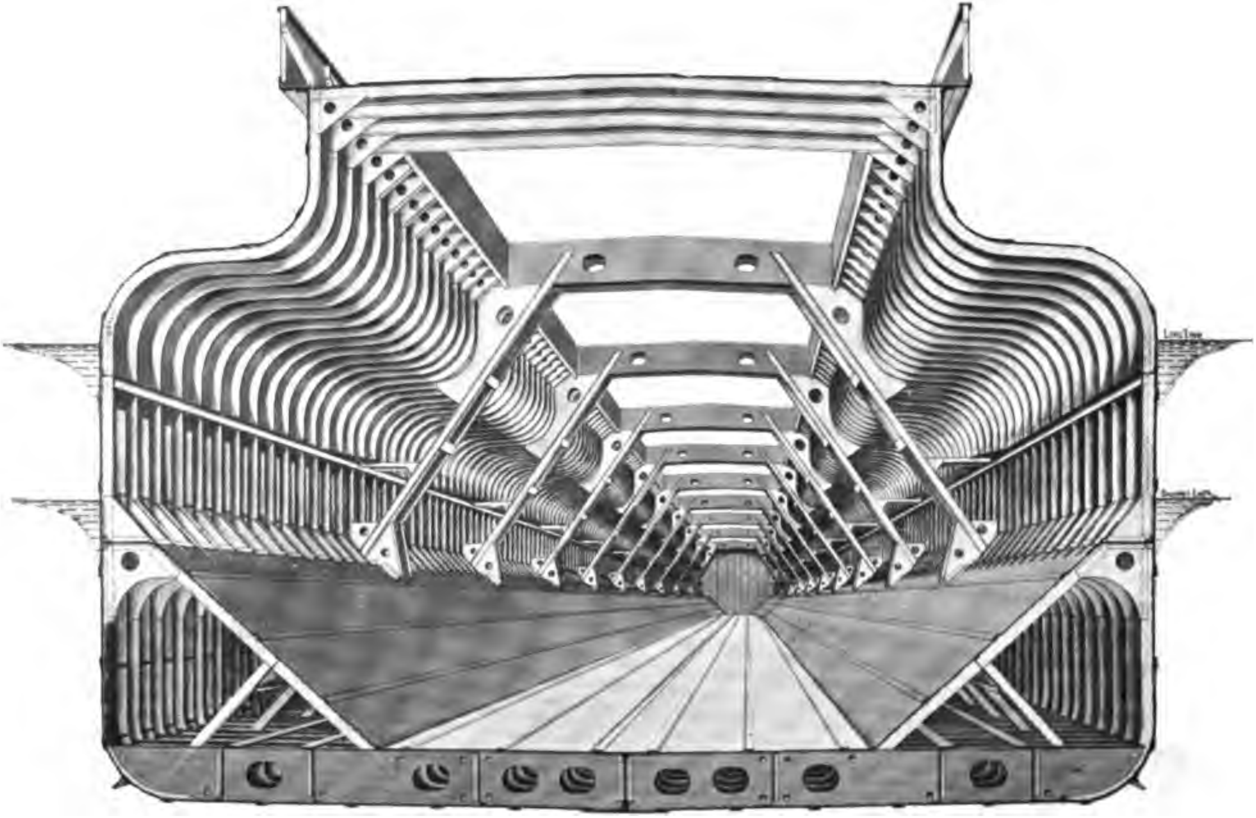


Fig. 47.—Hold View of special Self-trimming Type of Turret Steamer for Coal, Ore, and Timber Trades.

Engines aft; no bulkheads between collision and boiler-room bulkheads; long hatch; large water-ballast capacity. Dimensions, 360 ft. 0 in. B.P. × 51 ft. 0 in. moulded × 26 ft. 6 in. depth moulded (harbour deck.)

Side Stringers dispensed with.—Fig. 46 shows a turret with no hold or harbour deck beams, widely spaced tubular steel pillars, and no stringers between the inner bottom tank side and the frame heads. The omission of these side stringers is compensated for by increasing the thickness of the side plating in proportion to the area unsupported. The frame spacing is increased to 30 inches, and on this account additional depth and thickness is given to the frames. Although little, if any, saving is effected in weight of material by this system, there is nevertheless much to be said in favour of greater simplicity of construction, and there is doubtless an advantage in the wider frame spacing and deeper framing, by the facility which is afforded for easier accessibility in examining and cleaning and painting the frames and shell. The omission of the side stringers is also an advantage in carrying bulk cargoes. See also "Stringerless Vessel," page 91.

Bulkheads dispensed with.—The latest development of the "Turret" is the vessel whose internal view is shown in fig. 47. Here, the machinery is placed right aft, and between the collision bulkhead and the boiler room bulkhead there is a continuous clear hold space. In view of the exceptional transverse strength obtained by this method of construction, the *structural* necessity for bulkheads, other than those mentioned, is dispensed with.

An enormous amount of water ballast, reaching to over one-third of the deadweight, is carried in this special form of double bottom tank. It will be seen that the watertight inner bottom plating is lifted from the top of the floors on each side, and terminates at the lower side stringer. A continuous hatch extends almost the whole length of the hold. A system of oblique double channel struts and ties, in conjunction with heavy box beams across the turret deck at intervals, and the means of securing them and developing their utmost efficiency, is shown in the sketch.

This type of vessel recommends itself more particularly for coal, ore, and timber trades, especially if long over-sea voyages have to be made in ballast. The advantages of such a clear hold for these trades are obvious. This arrangement is specially suitable where coal is discharged by grabs, as the self-trimming form of the bottom of the ship brings the coal inside the line of the hatch coamings.

Other advantages possessed by the turret steamer may be enumerated as follows:—

There is no possible means of heavy shipped seas finding lodgment on either the turret or the harbour decks, as no continuously closed bulwarks are fitted to the vessel. The turret erection is an ideal feeder to the lower holds in vessels carrying grain and other bulk cargoes, and therefore, when fully loaded, the danger of a cargo shifting is rendered impossible in the lower holds, while any shift of cargo that might take place in the turret erection itself would have so little effect upon the stability of the vessel as to be unnoteworthy. The rounded form of the gunwale also contributes to the better stowage of these cargoes. The height of the turret deck (10 to 12 ft. above the load line), on which are situated all the hatches and ventilators, also the engine and boiler casings, companion-ways, etc., is a source of safety and protection to these important parts.

It will be noticed, in looking at the midship sections, figs. 39, 40, 42 to 47, that, as far as possible, all connections of plates to one another have been effected by flanging or joggling, thereby dispensing with the usual connecting angle bar and packing. The midship sections show that the floor plates are flanged as well as also the intercostal girders in the double bottom at their upper and lower edges. The edges of the shell plating and inner bottom plating are joggled. By adopting this system, all the plating bears close upon the surface of the material to which it is attached. This confers the great advantage of improving the efficiency of the riveting by having fewer thicknesses to rivet through, not to mention the great saving by relieving the vessel of the weight of packing.

The additional depth and strength provided by the continuous turret erection makes less necessary additions to structural strength on account of the proportion of length to depth.

The turret deck is fitted with the usual loading and discharging gear—winches, derricks, etc.—and, following the general tendency in these days, the masts are short, and make no pretence of carrying much sail. Indeed, their chief function is to support the derricks. Objection has been lodged against the turret steamer because of its un-shiplike appearance; but the turret vessel is essentially a cargo steamer, and a deadweight carrier. Moreover, it only resembles, in a more advanced form, the tendency of the ordinary cargo vessel, which, by its full-formed hull, shorter masts, and conspicuous smallness of sail (and in some cases no masts at all), together with its elaborate discharging and loading gear, is fast losing all the features which originally conveyed the idea of a ship. However, as cargo steamers are built to earn freights, any argument against appearance is unreasonable, so long as a satisfactory condition of seaworthiness is assured.

Recognizing the importance of making provision for the carriage of ballast when making long over-sea voyages without cargo, which is so usual an occurrence in these days of keen competition, figs. 38, 41, and 47 show arrangements for carrying water ballast, whereby the draught is increased from the light line shown to a deeper water-line allowing considerably greater immersion, and trimming the vessel reasonably by the stern, in order to secure the most favourable conditions for the propeller. Of course, where a huge, deep tank is fitted, such as shown amidships in fig. 41, the bulkheads bounding such tanks require to be most efficiently stiffened, and in the profile are shown the deep vertical webs which the builders fit to these bulkheads, in addition to other stiffening.

The space on the harbour deck at the sides of the turret erection lends itself and is easily utilized for the carriage of imperishable deck cargoes, such as timber, etc.

While the freeboards of all ordinary ships which fully comply with the structural requirements of their respective types as laid down by the Board of Trade standard, may be determined on a minimum percentage of reserve buoyancy, exclusive of erections which are treated and allowed for separately, the "turret" and other self-trimming steamers may be treated in a like manner, for although they may differ in design, they nevertheless belong to the full scantling type in respect to strength.

It is patent to every intelligent observer that, valuable as the turret erection is in affording strength and buoyancy, yet the buoyancy of the turret erection could not reasonably receive the same credit in the matter of freeboard as the same amount of buoyancy distributed over the whole width of the harbour deck as in an ordinary vessel. Hence the Board of Trade Freeboard Tables and Instructions allow as much as 70 per cent. of such buoyancy as being effective in determining the freeboard, which is measured from the turret deck, a fact in itself testifying to the value of the turret erection.

A few extracts from the Board of Trade Freeboard Rules regulating the depth of loading of turret deck vessels and vessels of similar types, will no doubt greatly assist in conveying a clear idea of the basis upon which such vessels are treated in the assignment of their load lines.

"A 'turret' is a strongly constructed continuous erection at the middle line of a vessel, forming with the main or harbour deck an integral part of the hull, and of a breadth not less than five-tenths the greatest breadth of the vessel, and a height not less than 25 per cent. of the moulded depth."

"Hatch coamings at least 2 ft. high, and casings to engine and boiler openings at least 4 ft. 6 in. high, to be fitted above the 'turret' deck."

"The reserve buoyancy required by the Tables to be estimated by taking 70 per cent. of the volume of the turret. The height of the turret allowed for is not to exceed 25 per cent. of the moulded depth."

"The moulded depth of the vessel to be taken to be the depth at side from the beam line, as before defined, to the top of the keel."

"The transverse and longitudinal strength of the vessel to be regulated by that required for a 'three deck' vessel of the same length, breadth, moulded depth, and coefficient of fineness; and the scantlings of the turret are to be determined so that the stress per square inch upon the material of the turret amidships shall not exceed that of a standard vessel of the same dimensions and form, and having scantlings equal to the requirements of the 100 A class in Lloyd's Register (1885) for 'three deck' vessels when loaded to the freeboard given in Table A, after deducting 12 per cent. from the same."

TRUNK STEAMERS.

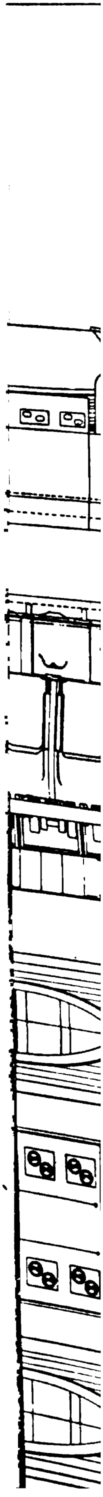
Figs. 48 and 49 are plans illustrating in profile and midship section what is known as the "trunk" steamer.

The inventors of this type of vessel are Messrs Ropner & Son, the well-known shipbuilders of Stockton-on-Tees. The trunk steamer is essentially a cargo vessel which possesses special facilities for the stowage of bulk cargoes, and advantages in the navigation of the vessel. On referring to the midship section, fig. 49, it will be seen that, up to the gunwale, this vessel is in every respect similar to the ordinary type of cargo vessel. She has a cellular double bottom, and is framed on the web frame system, thereby dispensing with a tier of hold beams, and leaving the whole space perfectly clear, with the exception of the hold pillars, which are widely spaced. Instead of web frames, the deep frame system may be adopted. In addition, these vessels have a poop, bridge, and forecastle constructed in the usual way.

The special feature of this vessel is the trunk erection. This trunk is strongly framed and plated, and can be made thoroughly substantial. It extends from the poop to the bridge, and from the bridge to the forecastle, into each of which the sides of the trunk are scarphed. The height of the trunk is about 7 ft.—that is, the height of poop, bridge, and forecastle—with which erections the top of the trunk forms a continuous deck. The breadth of the trunk is about half the beam of the vessel. Strong through beams are placed, where necessary, at intervals at the base of the trunk (see figs. 48 and 49). These strong beams greatly assist in maintaining the transverse strength. Apart from these strong beams, the trunk space is entirely open to the lower hold, and, as the midship section shows, the ordinary main deck beams are cut at the sides of the trunk. This apparent weakness, however, is fully overcome by the strong connection made between the trunk sides, the beams, and the pillars (see fig. 49). First of all, the deck plating is flanged into the trunk side. The hold pillars are of channels, or tee bars, fitted back to back, one of which bars extends some distance up the trunk side plating, to which it is riveted, and further, the pillars are bracketed to the deck beams and deck plating, as shown. Thus the trunk sides, being thoroughly connected to and scarphed into the poop, bridge, and forecastle, and supported as they are by extra strong hold pillars, afford ample strength for carrying the beam ends and supporting the main deck.

The trunk side frames, and the beams supporting the trunk deck, are all of about the size of the main frames of the vessel, and connected by brackets as shown in fig. 49.

As all the principal hold hatchways are situated upon the trunk deck, the trunk deck beams are necessarily cut at the hatch sides; but, as the midship section shows, the hatch sides are well supported by large web plates fitted between the trunk deck and main deck strong beams. The deck area of the



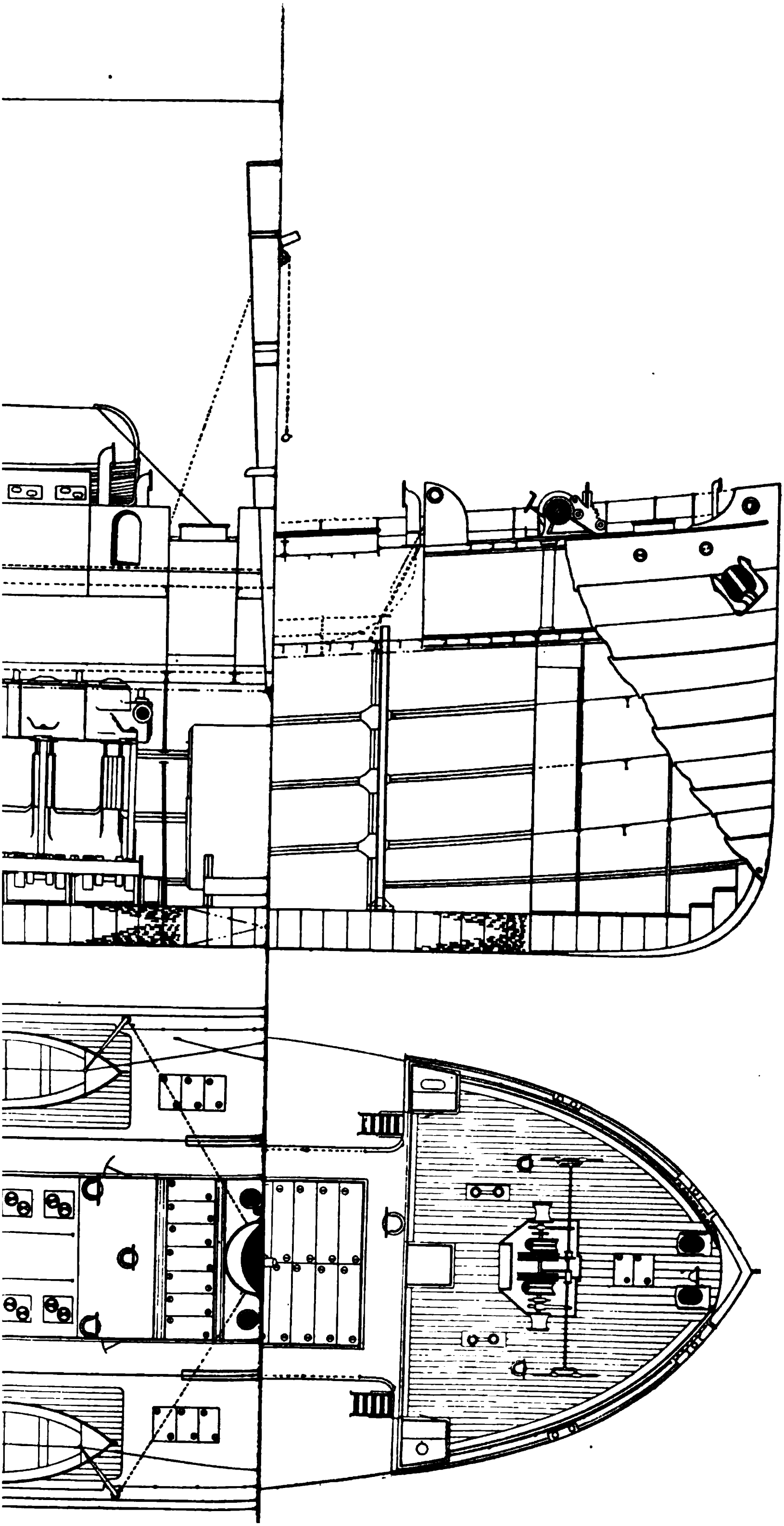
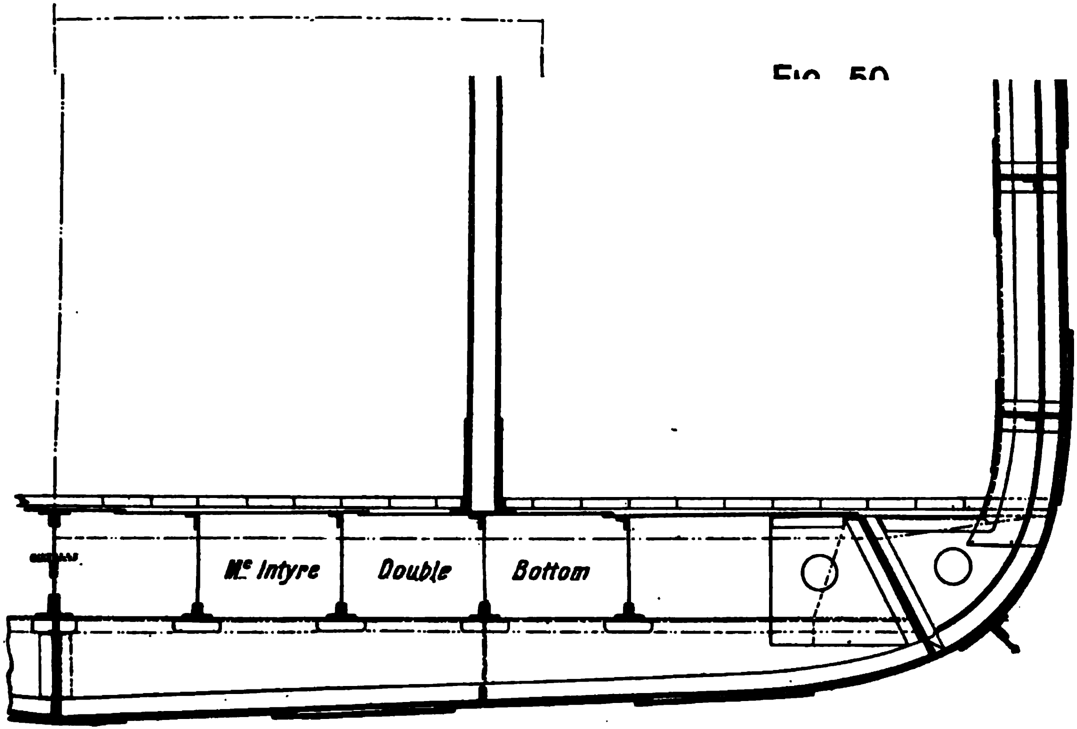


Fig. 50



trunk deck is increased by extending the deck plating about 1 ft. beyond the trunk sides, and this being practically the navigating deck, hand rails are placed along each side for protection, as shown.

The great advantage of having the navigating deck 9 or 10 ft. above the load water-line is a feature which every seaman can appreciate.

Moreover, as all hatchways, ventilators, and deck openings are situated either on the trunk deck, or on the poop, bridge, or forecastle, the protection which is afforded to these important parts, including the engine and boiler openings, is very apparent.

In the loading of bulk cargoes, the trunk forms an excellent feeder to the main holds, in addition to possessing the facility for self-trimming. The main deck is either fitted with open rails, or closed bulwarks of the usual form, as may be desired. Owing to the substantial nature of the hold pillars, and the excellent support they give to the trunk side and main deck beams, they are spaced at wide intervals apart, and by this means the possibilities of broken stowage are minimised. The main deck outside of the trunk is well adapted for the carrying of timber, cattle, or other deck cargo. In some cases, cargo skids or platforms at the sides of each hatch are fitted, extending from the level of the trunk deck to the sides of the vessel, for convenience in discharging cargo.

PRIESTMAN'S SELF-TRIMMING STEAMER.

Fig. 50 is a midship section illustrating another type of self-trimming steamer. The design is the patent of Messrs J. Priestman & Co. of Sunderland. The principal feature is an erection about 5 ft. in height extending from stem to stern. The top breadth of this erection is about half the moulded breadth of the vessel, and it forms the navigating deck. The hull from the keel up to the gunwale is of the ordinary form and construction. The diagram illustrating this vessel shows her to be built upon the web-frame system, thereby dispensing with hold beams; but, if preferred, deep framing might be adopted instead, or the ordinary frame and reverse bar (or some equivalent), together with widely-spaced hold beams. But as it is necessary for trimming purposes that the erection be in free communication with the main hold, the transverse strength of the vessel in way of the main deck is maintained by means of widely-spaced bulb plate beams well kneed to the web frames, and each supported by two hold pillars formed of double channel bars fitted back to back, which are bracketed at the top to the beams, and at the bottom to the tank top-plating.

The sides of the erection slope from the navigation deck to about 2 ft. from the gunwale, in order to increase the facility for self-trimming. The main frames from the tank side to the gunwale are channel bars.

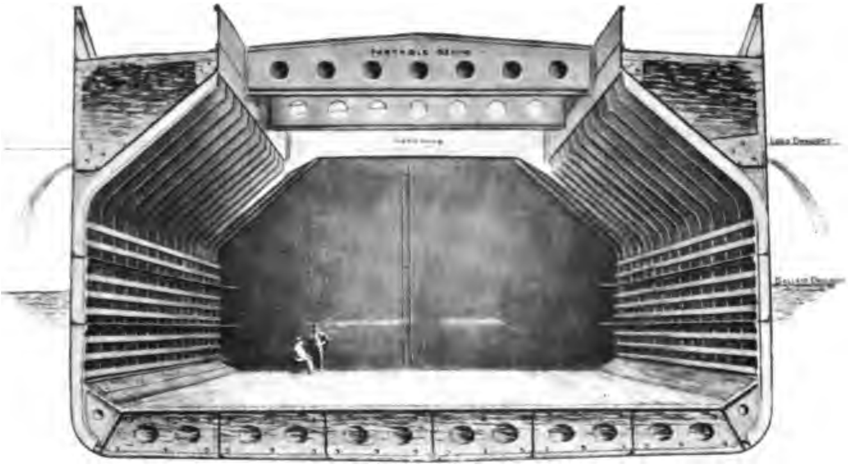
The self-trimming erection also is framed by means of channel bars which are kneed on to the main frames, and extend continuously from one side to the other, excepting in way of the hatches. Support is afforded to the sloping sides of the erection by means of large bracket plates on every strong beam (see fig. 50).

The navigation deck is supported by large web plates fitted between this deck and strong main deck beams immediately above each hold pillar (see fig. 50). It is also further supported by means of large bracket plates placed in a fore and aft direction at the angle of the navigation deck with the sloping sides. All hatches, ventilators, deck openings, including the engine and boiler casings, are upon the navigation deck, and thus considerably more elevated than they would be in a vessel of the ordinary type. The erection forms a natural feeder to the hold, with which it is in free communication, and is therefore specially adapted for the carriage of bulk cargoes. The sloping sides of the erection obviously greatly facilitate the self-trimming of such cargoes. An ordinary open rail is fitted round the main deck for purposes of protecting the crew. As the sloping side of the erection offers little resistance to the inroad of beam seas which are liable to sweep over the vessel, a closed iron bulwark is fitted to the navigation deck, well stayed by means of bars of tee iron section or something equivalent. This not only affords protection to the seamen in their duties in navigating the vessel, but keeps the upper deck drier than it otherwise would be. The erection being continuous from stem to stern, with the top and sides blended into the main hull by the stringer plate being flanged as shown in the midship section, and the erection side plating flanged on to the navigation deck, there is no doubt as to the substantial nature of the self-trimming erection. Further, the hold pillars being widely spaced, the possibility of broken stowage of cargo is greatly reduced.

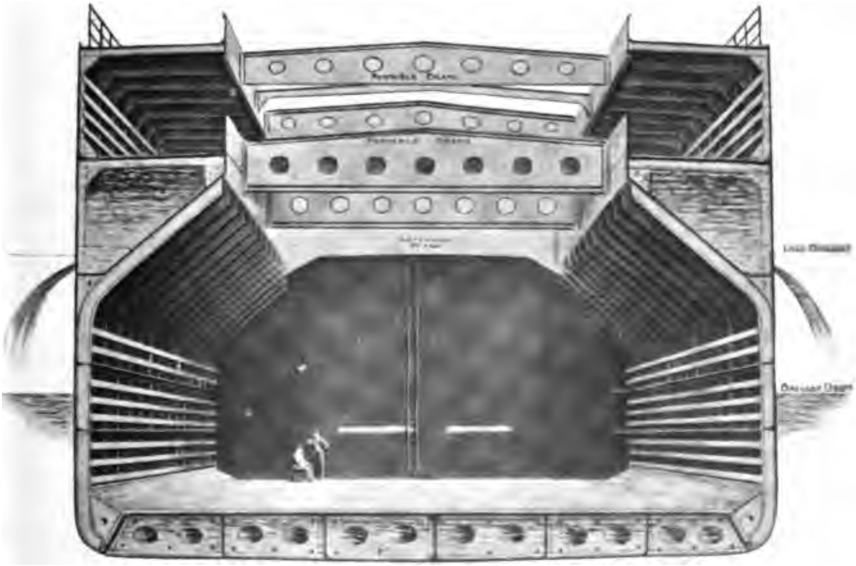
While the diagram shows this vessel to be built with a M'Intyre double bottom all fore and aft, excepting under the engines and boilers, where ordinary floors are fitted, a cellular double bottom might have been adopted equally well, had such been preferred. The sides of the self-trimming erection are specially arranged for the carriage of timber on deck; special provision for securely lashing the same from side to side of the vessel is provided by bar iron posts bracketed to the deck, spaced at intervals throughout the length.

CANTILEVER FRAMED SELF-TRIMMING STEAMER.

Figs. 51 and 52 illustrate in profile and section a noteworthy type of vessel which has appeared in recent years. It is designated by the builders, Messrs Sir Raylton Dixon & Co., Ltd., Middlesbrough, as a Patent Cantilever Framed ship, under the patents of Messrs Harroway and Dixon,



Hold View of Cantilever Framed Ship, Single-Deck Type. (See p. 78.)



Hold View of Cantilever Framed Ship, Shelter-Deck Type, for Passengers, Cattle, etc. (See p. 78.)

Fig. 52a.

John Priestman, and Livingston and Sanderson. On comparing this vessel with the midship section shown in fig. 50 (Priestman's self-trimming steamer), while many very important differences will be observed, yet there are several features of identical character. Indeed, it would appear that the one vessel is the outcome of the other; hence presumably the inclusion of the name of Mr John Priestman with that of Messrs Harroway and Dixon in the patent.

The first feature which recommends itself in this type of vessel is the absolutely clear hold space. This is always an exceedingly desirable arrangement from the shipowner's aspect.

The dimensions of the steamer illustrated are: length B.P., 360 ft.; breadth moulded, 51 ft. 9 in.; depth moulded, 28 ft. 4 in.

An ordinary vessel of this depth, from a structural point of view, would belong to the three deck class, requiring, below the upper deck, at least two tiers of beams with their broad stringer plates, and also hold pillars. Both beams and hold pillars, as just indicated, have been entirely dispensed with. Even the side stringers are of an exceedingly compact form, scarcely projecting beyond the cargo battens. This is brought about and made possible by a unique system of construction which is described herewith. The vessel has a double bottom for water ballast built in the ordinary manner. The frames are usually of deep bulb angles, and extend vertically from the bilge—where they are bracketed to the inner bottom side plating—for a considerable distance up the vessel's side. Several feet before reaching the deck, however, they bend inwards and are directed diagonally to the base of a deep fore and aft girder. This girder is continuous all fore and aft underneath the deck, but in way of all hatches it projects above the deck, forming the hatch coamings.

Externally, this vessel differs little, if any, from the ordinary type—the upper deck being the full breadth of the ship. To carry this deck, frames of smaller section are bracketed to the knuckles (the bend previously referred to) of the main frames, and kneed to the deck beams in the usual way. The beams at the sides of the hatches are bracketed to the coaming plates and to the heads of the main bulb angle frames. Reference to the midship section, fig. 52, shows that the outside shell plating is carried up to the deck in the usual way, passing vertically over the junction of the deep bulb angle frames and the smaller frames above. At the deck stringer the connection presents no unusual feature. But, as indicated in fig. 52, the space between the main bulb angle frames, the outer frames, and the deck is arranged for the carriage of water ballast. Two sides of this water-ballast space, as pointed out, are enclosed by the outside shell plating and the deck plating. The watertight boundary on the other side of this triangular space is effected by the plating on the main frames extending continuously from just above the knuckle bend to the fore and aft deck girder aforementioned. The connection of this inner plating to the outside shell plating at the lower extremity, is wrought by carrying the plating horizontally—supported upon brackets riveted to the knuckles of the main frames, and by a continuous angle to the outer shell plating—for a distance of about 2 feet, at which point it strikes the main frames.

It will now be understood whence comes the term "cantilever" as describing this system of construction; the deck and hatch coamings are carried by the cantilever made up by the formation of the upper side ballast tanks—the over-reaching main bulb frames, held at their heads by the half beams to which they are thoroughly bracketed, and carrying on their ends the continuous fore and aft girder, which, in its turn, forms the hatch coamings. The great strength developed by this framework, covered on all sides by steel plating, accounts for the non-necessity of hold pillars and a tier of 'tween deck beams, while the deep bulb angle frames dispense with the necessity for a tier of hold beams. All the foremost classification societies class these vessels.

This system of construction possesses other advantages than even the conspicuous one of clear hold spaces. These may be briefly enumerated as follows:—

(1) Greatly increased water-ballast capacity, amounting to nearly one-third of the total deadweight. Even sea experience is not required to understand the terrible plight of a modern bluff-ended cargo steamer, with box-shaped midship section, in a gale, under-ballasted. She sits like a balloon on the surface, with only slight immersion, and consequently little grip of the water, and only intermittent effective advantage and use of the propeller, racing, as it does, a large proportion of its time out of water. In conjunction with judicious proportions of depth to breadth, the "cantilever" vessel is more efficiently ballasted for the insurance of good behaviour at sea in an unloaded condition, than would be the case were all this water ballast laid along the bottom. The ballast is pumped up in the ordinary way, and by simply opening sluice valves the tanks are self-emptying. There is also the advantage of the water ballast being distributed over the vessel's length, and not concentrated locally, as in the case of midship deep tanks; this obviates abrupt stresses. While the space occupied by the side ballast tanks is lost, as far as being available for cargo is concerned, yet it is well understood that this is the very space in the hold of an ordinary vessel which is most difficult to efficiently fill with bulk cargoes, such as grain, coal, etc. Against the loss of this least valuable hold space must be placed the consideration that this water-ballast space is not included in the vessel's register tonnage, and is therefore exempt from tonnage dues—this, of course, only on condition that it is exclusively a water-ballast space, entered by manholes only.

(2) No trimming expenses.

(3) The system of construction permits of long, broad hatches being introduced. The hatches in fig. 51 are 30 ft. wide. The necessity for

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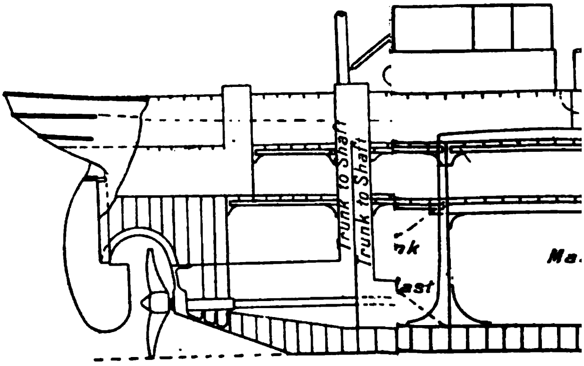


numerous portable and deep transverse webs should not be overlooked. See figs. 51 and 52.

(4) The full width of deck area is preserved, which is a consideration in the event of carrying deck cargoes.

Some New Features in Modern Shipbuilding.

While several changes and improvements have taken place in recent years in many of the details of ship construction, probably the greatest and most startling of these changes, and, it may be truly said, improvements, have taken place in a number of vessels designed by Mr H. B. Wortley for the Ocean Steamship Company of Liverpool, managed by Mr Alfred Holt. When first these innovations were propounded, they were looked at in consternation by many experts; but the fact that a number of these vessels have been built, and have sailed several round voyages to China and back in all weathers and seasons, and have had unstinted praise lavished upon them by the men who have handled and manœuvred them, in addition to the compliment that some of the features have so commended themselves to practical shipowners that they have reproduced them in their new vessels, proves that the advance is in the right direction. The principal innovations referred to are as follows:—

1st. No sheer.

2nd. More widely spaced transverse framing.

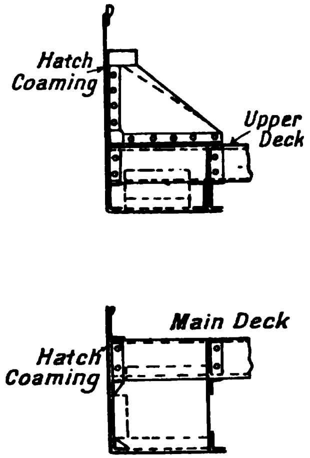
3rd. The substitution in the main hold of two pillars instead of the usual numerous stanchions, and a modification of the same system in the other holds.

4th. The usual form of stern frame for single-screw vessels dispensed with, thereby enabling the shipbuilder to get rid of much useless material (and hence weight) in that locality, known as the dead-wood in wooden vessels, at the same time improving the steering qualities, while a special arrangement has been introduced to carry the rudder, which also is of special design.

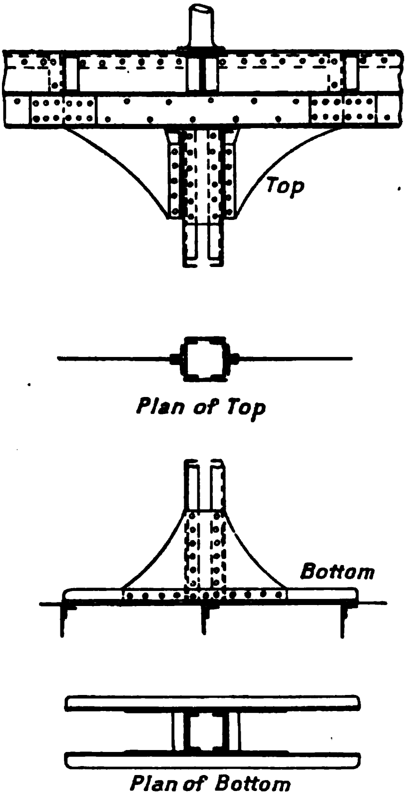
5th. Cement. The bottom of the vessel inside the ballast tanks is not cemented.

Reference to figs. 53, 54, 55, and 56 graphically illustrates most of the points just mentioned. It is advisable, however, to look more particularly into the features or innovations just enumerated in order to determine more fully what results are entailed in their adoption.

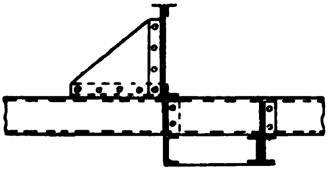
1st. Sheer.—That sheer is not given to a vessel for purposes of strength should be clearly understood, for while increased depth over the midship length undoubtedly contributes to increased effective longitudinal strength, yet the increased depth which sheer gives towards the extremities is utterly useless for this purpose, as the longitudinal bending moments decrease from midships towards the ends.



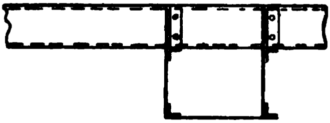
Section through Main Hold Hatch Side in way of Pillars.



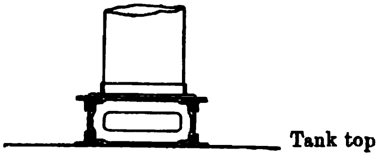
Top and Bottom of Pillars in After Main Hold.



Section at A B (see fig. 53).



Section at C D (see fig. 53).



Section through Stool under Main Hold Pillars.

Fig. 55.—Detail Sketches of Vessel illustrated in fig. 53.

The value of sheer lies in the increased reserve buoyancy which it provides towards the ends of a vessel, affording increased lifting power, when she is labouring among head or following seas, which in turn means a drier deck, and greater protection to the crew. Consequently vessels with less than the Board of Trade standard sheer are penalized by having the freeboard increased, while vessels with sheer in excess of the standard obtain a reduction in freeboard. Spar and awning deck vessels are exceptions to this rule.

Now if by any other means a vessel can be provided with ample reserve buoyancy at her ends, the same purpose for which sheer is given will be served, and it will be better from a structural point of view to take the increased depth which a certain sheer would have provided, and add it uniformly all fore and aft to the depth of the ship. By this means not only is the total amount of reserve buoyancy above the upper deck maintained, but, as previously pointed out, the longitudinal strength of the ship is effectively increased.

In these special vessels with which we are dealing, the necessary reserve buoyancy at the ends is abundantly supplied by means of a high poop and forecastle (about 9 ft.), which cover a considerable length at each end. Sheer is therefore unnecessary.

In addition to the aforementioned erections, a well-constructed and efficient bridge covers a considerable portion of the middle length, including the engine and boiler openings. In order to avoid the appearance of being "hog-backed," which might result from a horizontal deck, a sheer is given to the bulwark line only, the sight edge of which is continued from stem to stern.

2nd. Widely-spaced Transverse Framing.—Whether a load line be assigned to a British vessel by a registration society or the Board of Trade, as previously stated, she must come under the test of Lloyd's 1885 Rules. It is therefore reasonable to expect that, if the transverse frames be more widely spaced than is specified in these rules for any particular size of vessel, compensation, or, in other words, equivalent strength, must be introduced, and this is done in the vessels we are describing in the following manner:—

First.—As the transverse frames are spaced 36 in. apart instead of 27 in.—the maximum given in Lloyd's present Rules—the required transverse stiffness is obtained by increasing the depth of the framing; and as these ships are built on the deep frame principle, this is easily done by increasing the depth of the athwartship flanges of both the frame and the reversed bar. As fully described in *Steel Ships*, in dealing with the strength of girders, an increase in the depth of the deep framing not only increases the sectional area, but the moment of inertia also in a greater proportion than the sectional area. So that although the individual frames are heavier, their decrease in number ought to result in a lighter total weight of framing.

Second.—If widely spaced transverse frames be adopted in combination with the ordinary longitudinal framing, greater areas of unsupported shell plating would exist over the whole of the immersed surface of the hull, and the tendency would be for the shell plating to fall hollow, owing to the enormous pressure to which these areas would be subject. Something must therefore be done to provide the necessary rigidity. This can be effected by somewhat reducing the sectional area of the large, cumbersome side stringers required by rule, and compensating for this reduction by fitting additional side stringers of a more compact form. In this way the longitudinal strength would be preserved, while, at the same time, such strength would be more uniformly distributed, thereby reducing the area of unsupported shell plating. Fig. 54 shows an excellent arrangement of side stringers.

Every strake of shell plating has a stringer upon it, extending throughout its whole length, thus converting each strake with its accompanying stringer into a combined girder. The excellence of such an arrangement needs no further comment.

Third.—When the foregoing system of adopting additional longitudinal girders in combination with widely spaced transverse framing is not carried out, the required stiffness to the shell plating can only be obtained by increasing its thickness. Indeed, in the Board of Trade Freeboard Tables and accompanying Rules, the following paragraph is found relating to this aspect of a vessel's strength:—

"If the frame spacing be increased one-fourth, the thickness of all the plating, excepting garboard and sheer strakes, should be increased by $\frac{1}{20}$th of an inch over the thickness required in the standard ship. Other increases in spacing should be dealt with in the same proportion."

3rd. Hold Pillars.—Pillars, or some substitute for the same, are an absolute necessity in all ships. In vessels of comparatively small beam, middle line pillars alone are sufficient; but in larger vessels having greater breadth, the beams (decks) require additional support between the middle line and their connection to the frames. In figs. 53 and 54, which illustrate a vessel of 52½ ft. in breadth, both middle line and side or quarter pillars are required by Lloyd's Rules; but, as shown in the diagram, these are entirely omitted, with the exception of those shown in the profile, which are of exceptional construction and strength. In the *main hold*, which is the longest in the vessel, two hollow plate pillars, 21 in. in diameter, support the deck, the supporting strength being distributed throughout the length of the hold space by a very strong box girder well connected to the deck and beams and to the bulkheads by means of large brackets.

The thrust of these two pillars is distributed over the bottom of the vessel by means of a stool to which they are connected by angle rings—the stool in its turn being well connected to the inner bottom (see figs. 53, 54, and 55).

The *main 'tween-deck* pillars are 12 in. in diameter. They are connected to the deck at their lower extremity by an angle ring, and to the upper deck by a girder made up as shown in fig. 55 of plates and channel bars. This girder comes alongside the upper deck hatch coaming plate, which itself forms one web of the girder, and is extended along the upper deck over the full length of the main hold, so as to rest upon the bulkheads at the extremities of the space. A couple of angle bars along the top edge of this plate (excepting in way of the hatch) add additional stiffness to the girder. The continuity of these deck girders or stringers is preserved all fore and aft, though somewhat modified in form on account of the shorter lengths of the remaining holds. For a similar reason, a modification is made in the construction of the pillars in these holds. As shown in figs. 54 and 55, these are made up of two channel bars, assisted at intervals in their height by plate ties, and well connected to the deck girders and tank top by means of large brackets at the upper and lower extremities.

The 'tween-deck pillars for these holds are made of solid round iron, 6 in. in diameter, with large palms to both their feet and heads, thereby permitting a good rivet connection.

4th. Stern Arrangement.—The great innovation in the arrangement of the stern for the efficient support of the propeller, and in the construction of the rudder and the manner in which it also is supported, is clearly illustrated in fig. 56. Unlike the ordinary stern frames in single-screw steamers, both forgings and castings are conspicuous by their almost entire absence, the only item of this kind being a comparatively small steel casting for the boss. This extends, as shown in fig. 56, from a watertight flat immediately above the boss to the lowermost extremity of the aftermost watertight bulkhead, and is riveted to both the watertight flat and the bulkhead through palms on the casting.

The remainder of the propeller aperture arch is constructed of a U-shaped Siemens-Martin steel plate 1 in. in thickness. By this arrangement, both the longitudinal and transverse framing are thoroughly connected to the stern plating as shown by the detailed sketches in fig. 56. Such an arrangement at once dispenses with a very considerable amount of weight, and makes the structure of the stern a thoroughly combined and compact one, and experience has proved these vessels to be remarkably free from vibration. Loose rivets, so prevalent in ordinary stern frames, have so far been practically unknown.

The stern post proper, upon which the rudder is shipped, consists of a wrought iron tube, 1 in. in thickness and 21 in. in diameter; and to afford additional strength to the lower part of the post, where most of the stress from the rudder is sustained, a doubling or liner of the same thickness is fitted.

The rudder also is of unusual design. It contains no forgings nor castings excepting in the neighbourhood of the coupling, where a steel casting is necessary in order to obtain an efficient connection with the rudder stock. Apart from this, the rudder is entirely made of plates

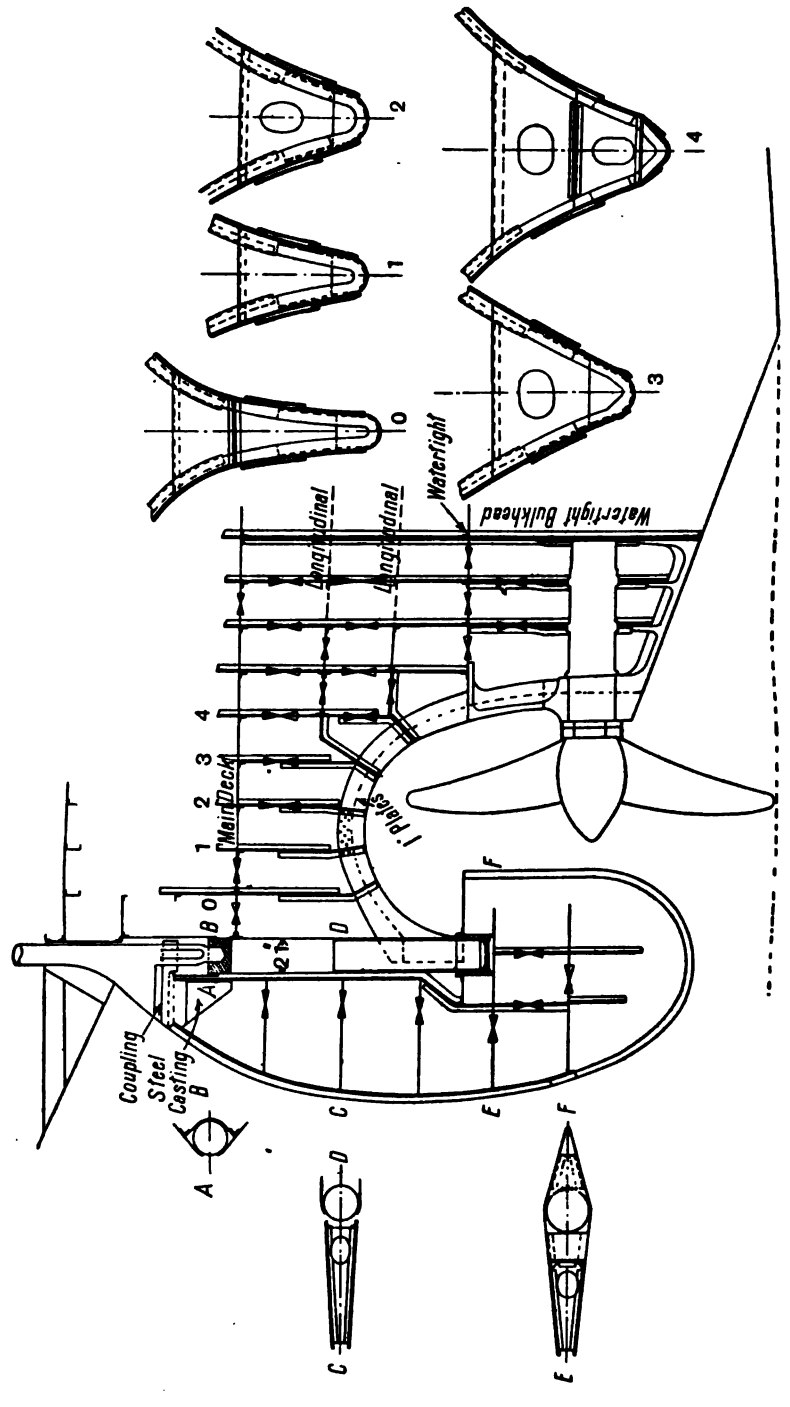
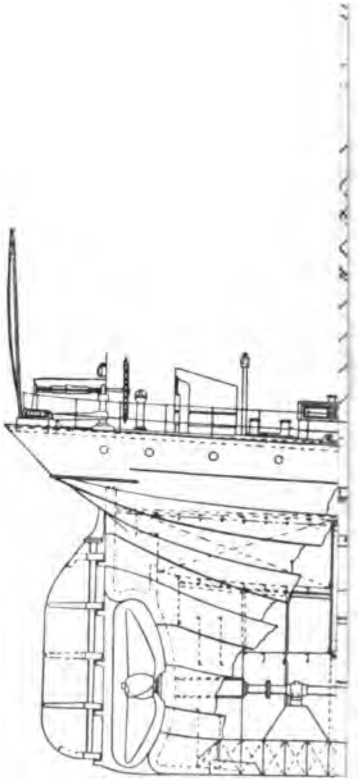
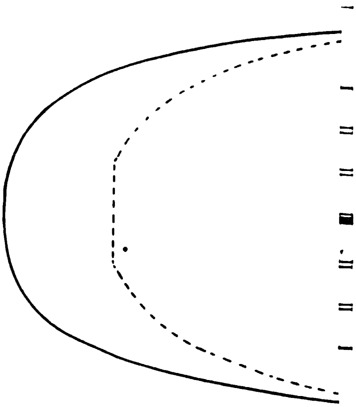


FIG. 56.—Stern arrangement dispensing with ordinary Stern Frame, and also Special Design of Rudder (for vessel illustrated in fig. 58).





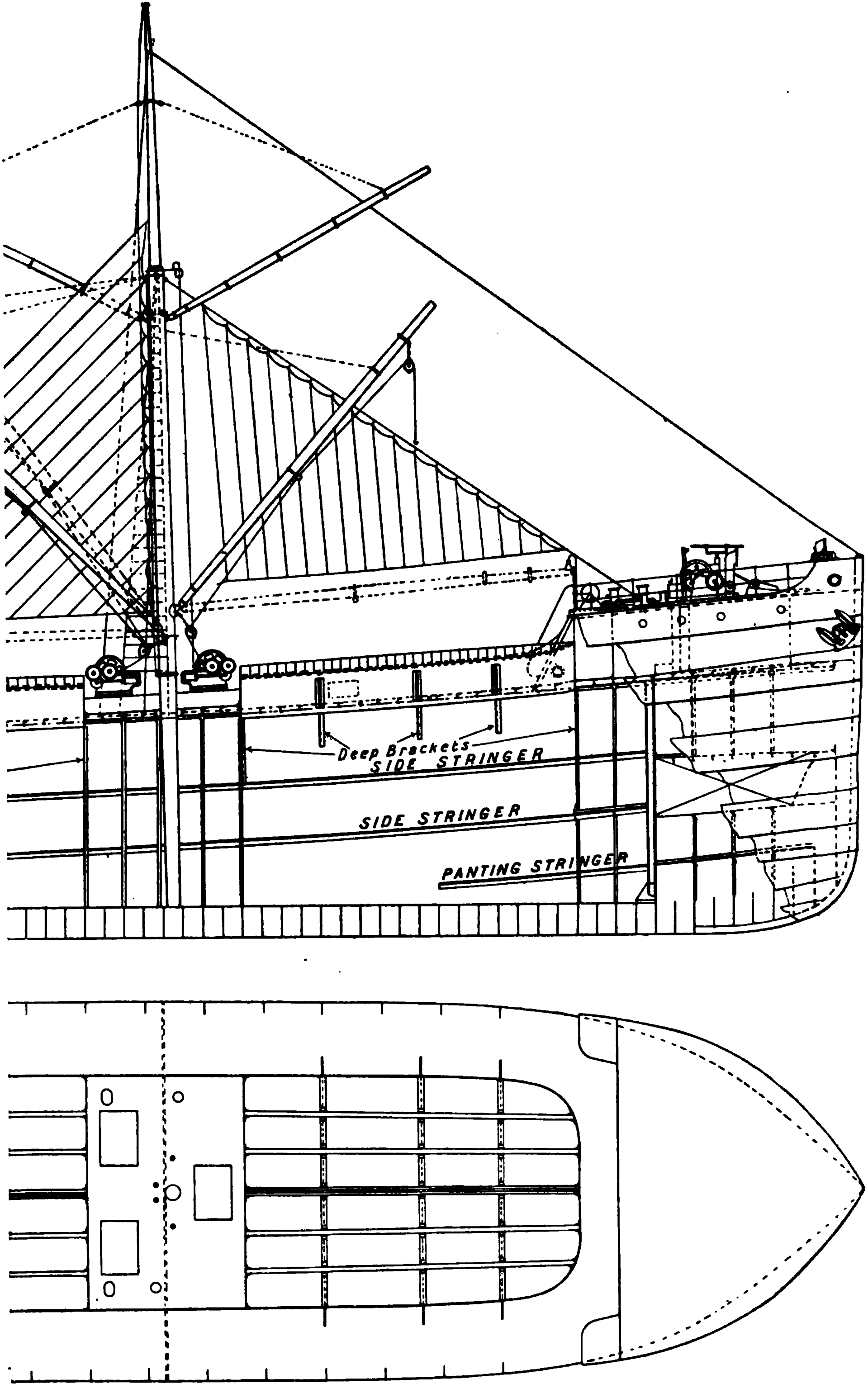
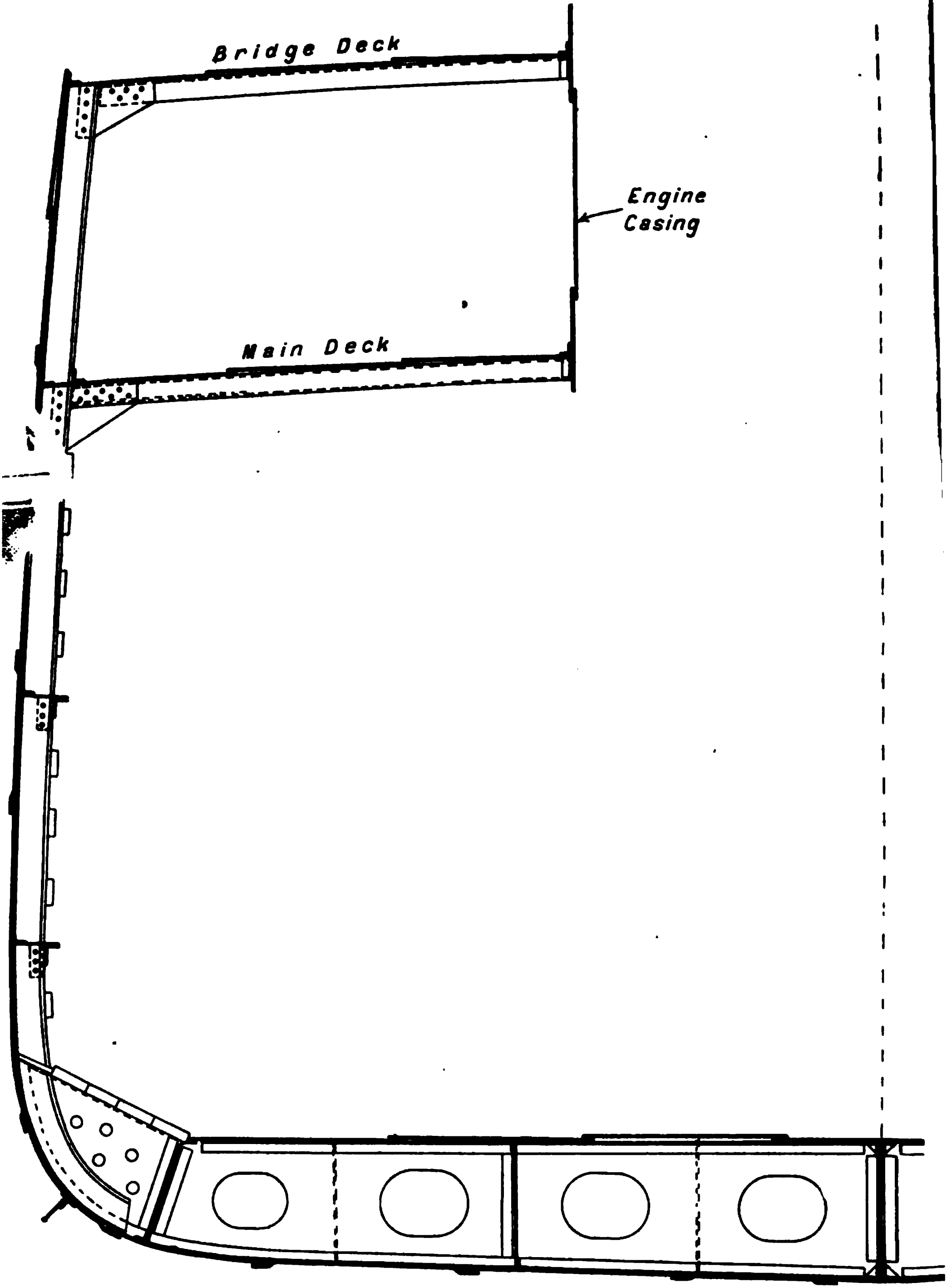

Deep Brackets
SIDE STRINGER
SIDE STRINGER
PANTING STRINGER

FIG. 58.

MIDSHIP SECTION OF STEAM COLLIER.



and angles (see fig. 56), and is designed to offer the least resistance to propulsion.

This rudder possesses the further advantage, owing to its form, of having the interior accessible in every part. The socket in the rudder into which the bottom of the stern post fits, is made of Siemens-Martin steel, with a white metal lining for a working surface.

For this construction of stern frame and rudder, it is claimed that a saving of at least 10 tons of weight is effected in vessels of this size.

These ships have proved exceptionally easy to handle, and thus the arrangement just described, in addition to its structural efficiency, enhances manœuvring powers.

5th. Cement.—A great saving of weight is effected in these vessels by the disuse of cement as ordinarily applied in cellular double bottoms. The inner surfaces of these tanks are well preserved by being coated with cement wash only, which must naturally be renewed periodically.

The use of cement has been more fully discussed in Chapter VIII. of *Steel Ships*, which deals particularly with the subject of "Maintenance."

STEAM COLLIER.

One of the essential features in modern steam colliers, especially if engaged upon comparatively short runs, is that, as nearly as possible, they be self-trimming. To obtain this condition, very large hatches with deep coamings are necessary. Figs. 57 and 58 illustrate a typical vessel of this class, built by Messrs S. P. Austin & Son, Ltd., Sunderland. Another desirable feature, in view of the heavy wear and tear to which they are subject, is, that the structure be of a thoroughly substantial character, while at the same time the system of construction should be as simple and compact as possible, leaving the holds as clear as consistent with structural requirements.

In the ship referred to, the framing is of an ideal character. Deep angle bulbs, in conjunction with the very compact form of side stringers shown in the midship section, fig. 58, compensate for reversed frames and a tier of widely-spaced hold beams—the vessel, because of her depth, belonging to the "two deck" class. Pillars are entirely dispensed with in the way of all hatches, support being obtained in lieu of these by large bracket plates, as shown in fig. 58 A, and spaced as indicated in the profile. These act as both struts and ties. In addition to these, extra deep bracket knees (see fig. 58 B) are fitted at the ends of each hatch, which, in conjunction with the extra strong (and pillared) hatch end beams to which they are attached, afford a further efficient means of carrying the deck and hatch coamings.

As the deck area is considerably reduced in way of all the large hatches, and as so many beams are cut in way thereof, it is necessary that additional strength be introduced both transversely and longitudinally. This is done as follows:—Between the forecastle and the bridge, and between the bridge and the poop, the bulb angle frames are made ½ in. deeper than elsewhere, and $\frac{1}{20}$th in. thicker. The deck stringer is increased in breadth and thickness, and all the deck plating between the gunwale and the hatch side is of stringer thickness. The sheer strake is doubled from two frame spaces within both engine and boiler room bulkheads, to the half length on each side of amidships. The great strength introduced by well-constructed and efficiently connected deep hatch coamings of considerable length is apt to produce working or buckling in the deck at their ends where this girder strength abruptly terminates. Hence it is necessary, in a vessel of this type, to maintain the fore and aft hatch coaming strength continuous, by making the girder continuous from the fore end of the fore hatch to within the bridge for, say, three frame spaces and tapered off, as shown in fig. 57; and similarly in the after well, from the poop bulkhead to within the bridge. In order to increase the efficiency of these fore and aft girders, a large, single angle, 6 in. × 6 in., permitting of double riveting, is used to connect them to the deck.

Within the bridge, the strength is abundantly maintained by the increased depth of the vessel, greater sectional area of deck plating owing to narrower engine and boiler deck openings, steel casings for full length of the bridge, bridge deck plating, etc.

The hatch coamings, as already stated, are of exceptional depth for self-trimming purposes, and the obviously necessary support is afforded by the bulb plate stays riveted to the deck, as shown at intervals in figs. 57 and 58 B. A noteworthy feature in the beam knee connections of this vessel is, that instead of lapping the beams on to the frames with the bracket places between, the three-ply riveting is obviated by stopping the beam at the inside of the bulb angle frames and using bracket knees 20 per cent. thicker than ordinarily required and three times the depth of the beam at upper deck, and with an increased number of rivets for connection in the transverse arm of the knee. Owing to no ceiling being laid on the tank top, the inner bottom plating is increased $\frac{1}{20}$th in. in thickness.

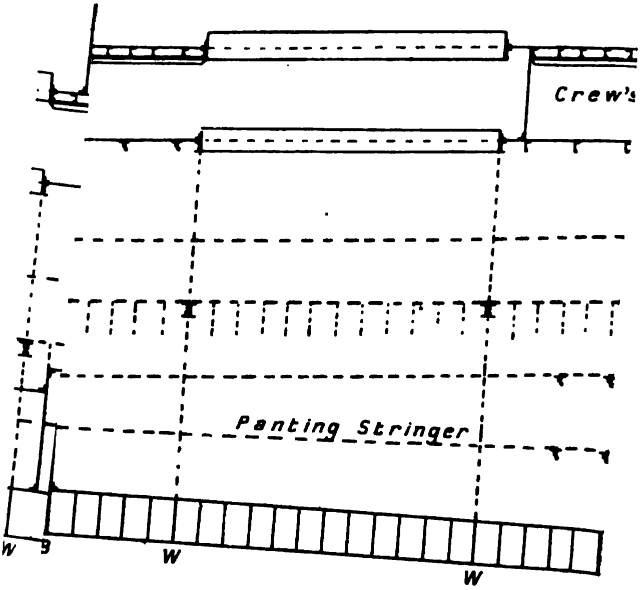
LARGE SINGLE DECK TYPE OF CARGO STEAMER.

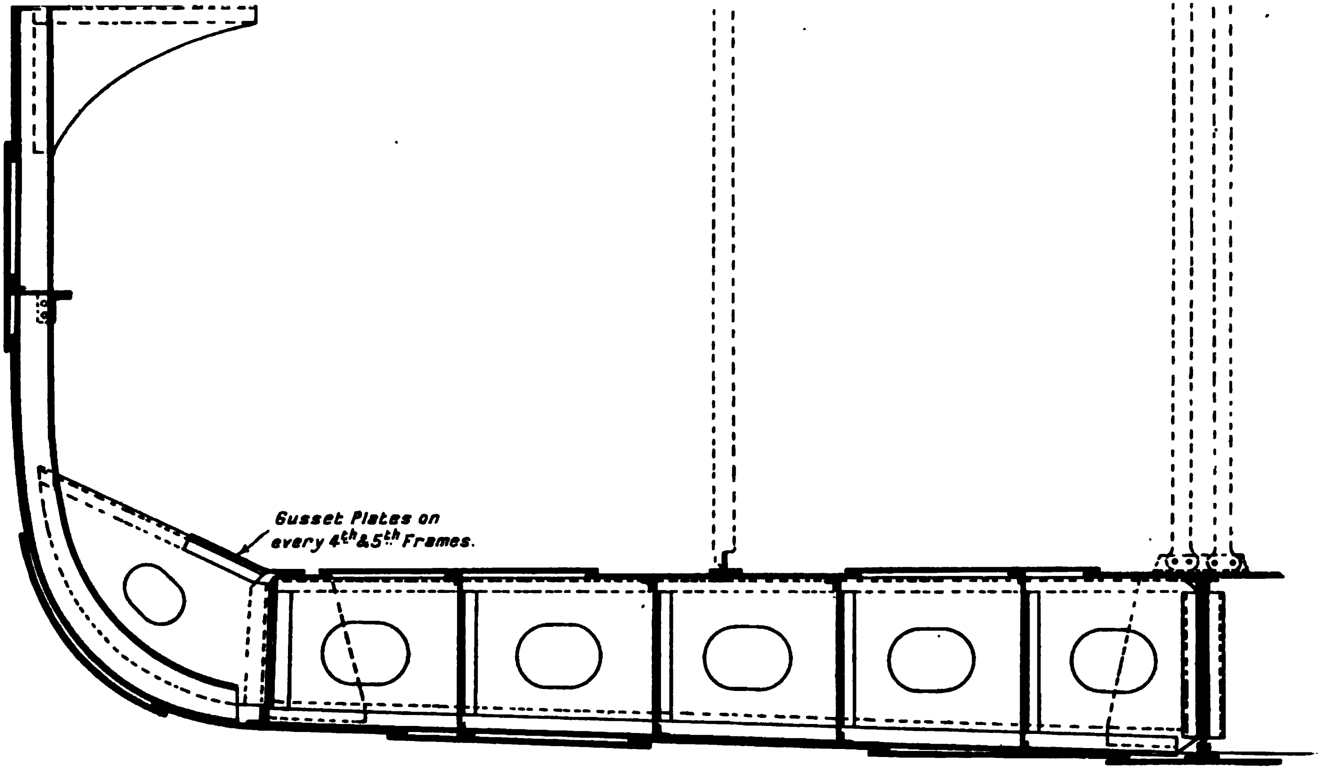
As a noteworthy example, illustrating the evolution in the system of construction of modern cargo steamers of moderate size, attention is directed to a shelter deck vessel, figs. 59, 60, 60 A and 60 B, built by Messrs Short Bros., Ltd., Sunderland. Her dimensions are:—

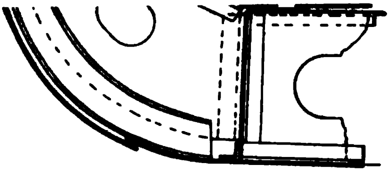
Length B.P., 373 ft. 0 in.
Breadth moulded, 50 ft. 0 in.
Depth moulded to upper deck, 27 ft. 7 in.

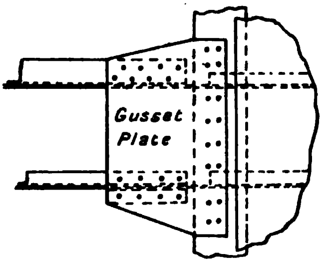
She is classed 100 A1 at Lloyd's.

LA




Gusset Plates on every 4th & 5th Frames.



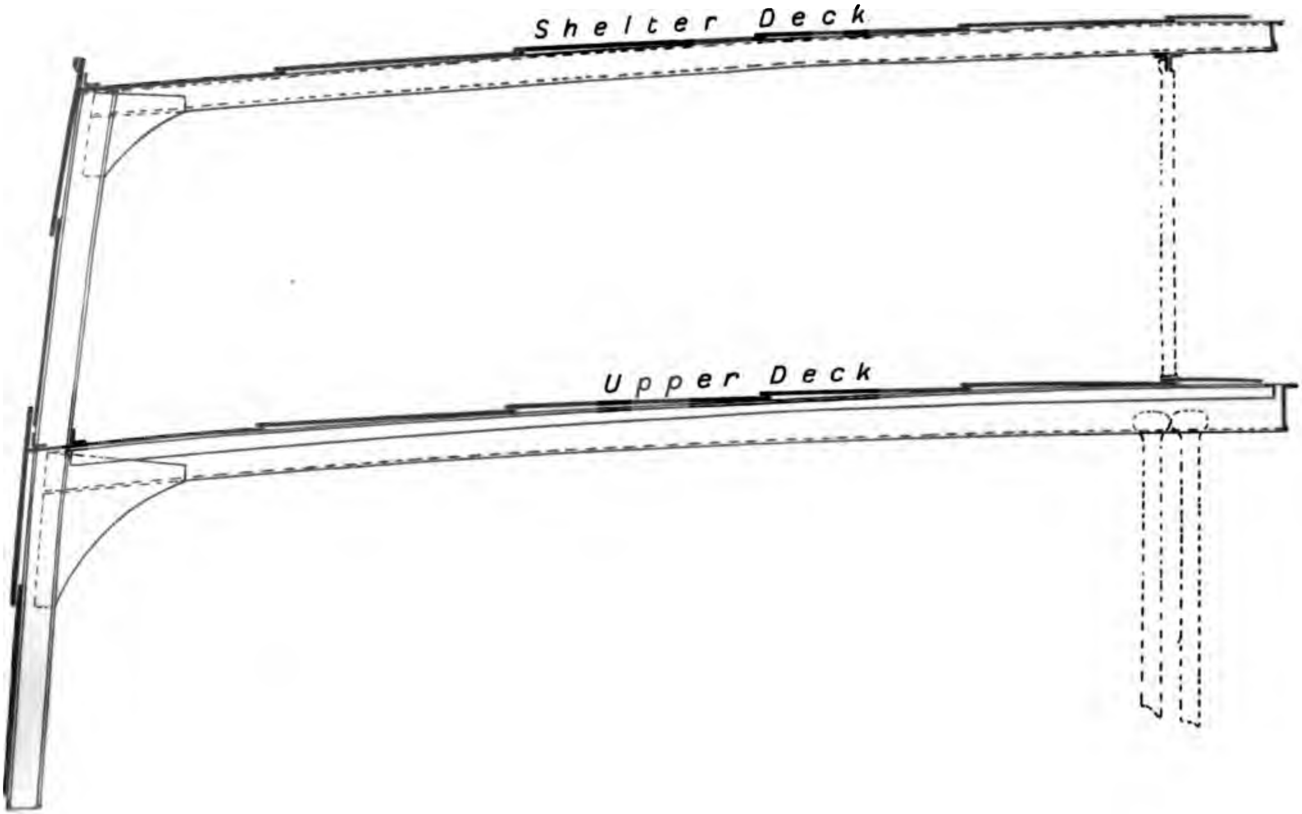


PLAN.
SHOWING GUSSET PLATE
CONNECTING TANK TOP
TO EVERY 4TH & 5TH FRAME.

FIG. 60B.

SECTION SHOWING UPPER STRUCTURE IN WAY OF THROUGH DECK BEAMS.

(See Figs. 59 and 60.)



She has a continuous shelter deck all fore and aft, 7 ft. 6 in. above the upper deck. This "'tween decks" is specially designed in order to be exempt from British tonnage measurement; consequently there is a permanent deck opening in the shelter deck aft, for which temporary provision only is made for closing in heavy weather (no cleats, tarpaulins, or means of battening down being permissible). At least one freeing port on each side below the deck opening is required for ridding the 'tween decks of any considerable quantity of water which may find its way through the deck opening, and, in addition, numerous scuppers are required on each side in the upper deck for a similar reason. As the shelter deck 'tween decks is not, therefore, an entirely closed-in space—*i.e.* an absolutely permanently closed-in space with provision for efficiently battening down all hatches and deck openings—it is observed that this vessel belongs to a new type of *single deck* vessel which has been evolved in recent years, though, as shown, she has a tier of very widely-spaced strong hold beams. Judging her purely by her depth (to upper deck), and ratio of depth to length, the standard vessel fixed for the guidance of all Registration Societies by the Board of Trade (Lloyd's 1885 Rules) requires two complete steel decks, and a tier of widely-spaced hold beams in addition. It is intended, therefore, to briefly describe the principal features in the construction, and to point out the compensation introduced in order to obtain so clear a hold space by getting rid of the obstruction of the complete steel deck aforementioned, with its tier of beams.

In the first place it will be well, perhaps, to recapitulate that the ship has had the transverse strength afforded by a tier of closely-spaced beams, and the longitudinal strength contributed by an $\frac{8}{20}$ in. complete steel deck, taken from her. The balance of strength is preserved by a redisposition of much of the structural material, reinforced. While the hold beams are retained, they are lifted from the position they would have occupied had the three tiers of beams been fitted, so as to be practically intermediate between the inner bottom and the upper deck beams (see fig. 60 A). In this new position, along with their broad thick stringer, they are very much more efficiently located in order to assist the frames in resisting the thrust from the side pressures. Of necessity, deep framing (or web framing) is introduced to compensate for the loss of the middle tier of beams. But a great factor in the transverse strength is lost by the omitted steel deck. In such cases the framing is based, not merely upon the 1st numeral obtained in the ordinary way, but by omitting the deduction of 7 (see page 23). But as just pointed out, the lower tier of widely-spaced beams, with its broad stringer plate, is very much more valuable (in conjunction with the deep framing) in its new position midway between inner bottom and the upper deck, and to this must be added the immense transverse stiffness introduced by the broad arched webs fitted in way of every strong hold beam, and extending from the inner bottom to the deck (see figs. 59 and 60 A); so that the final effect in determining the scantlings of the deep framing is that, while for the great omission of transverse strength aforementioned, the deep framing is first abnormally increased, it is again reduced owing to the immense value of the arched webs, and better disposition of strong beams and its stringer—the net result being a smaller deep frame than required under normal conditions.

1st numeral with deduction of 7 = 95·99 = deep frames 9½ in. × 3½ in. × $\frac{11}{20}$ in., spaced 24 in. apart.

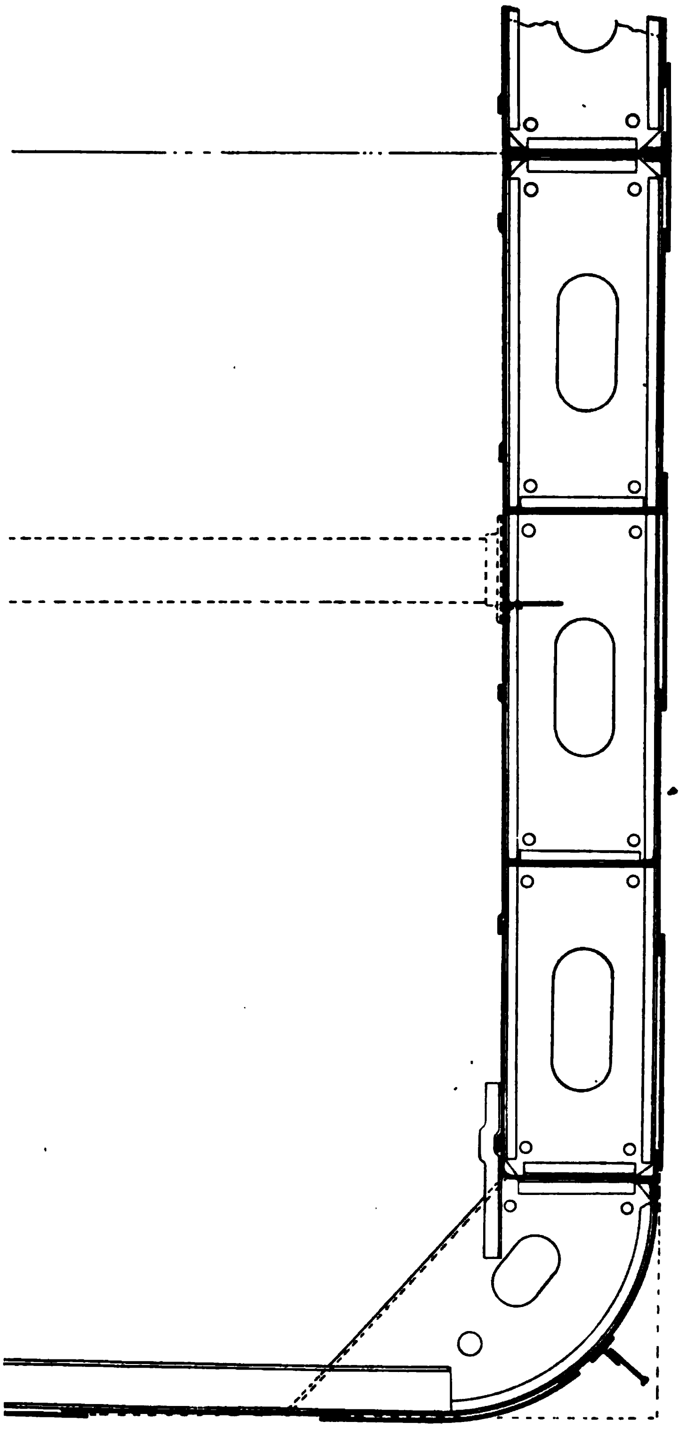
1st numeral without deduction of 7 = 102·99 = deep frames 10 in. × 3½ in. × $\frac{12}{20}$ in., spaced 25 in. apart.

The reduction for arched webs and better disposition of hold beams and its stringer, produce deep frames, 9 in. × 3½ in. × $\frac{12}{20}$ in., spaced 25 in. apart as actually fitted in the ship (increased, however, $\frac{1}{20}$ in. in thickness in way of No. 2 hatch, because of its large size and consequent lack of through beam strength)—a reduction of no less than 1 in. in the depth of framing.

For spacing and positions of the strong hold beams, and the arched web frames, see profile, fig. 59. Then, again, the omission of a complete steel deck and its broad thick stringer plate is a serious loss to the strength of the ship considered as a complete girder. Compensation is effected in this case by increasing the thickness of the shelter and upper deck plating, outside shell plating, and inner bottom plating, to that produced by using a 2nd numeral obtained without the deduction of 7 (see page 23). In this particular ship, deep bulb angle frames are used, and these are continuous right up to the shelter deck. But it is permissible to reduce the scantling of framing in shelter deck 'tween decks, and as this cannot be done when bulb angle frames are used, much extra strength is introduced which ought to receive consideration in valuing the whole ship girder. In this particular case an allowance was made in the shelter deck sheer strake and side plating, which are, in consequence, $\frac{1}{20}$ in. lighter than would otherwise be required.

It will be observed that, while the shelter deck beams are fitted to every frame, the beams to the upper deck are fitted to alternate frames only, excepting at the sides of hatches and engine and boiler deck openings, where they are of smaller scantling, fitted to every frame. In order to more efficiently carry the hatch half beams, the hatch side coaming plates are carried down vertically to the depth of the deep hatch end beams, and given a 6 in. flange as shown.

As pointed out in dealing with the small single deck collier, page 87, there is a special tendency in single deck vessels to develop weakness in the form of buckling in the deck at the sudden termination of hatch coamings, engine and boiler casing coamings, and even at the ends of long steel deck-houses. To obviate this, it is advisable to make this girder strength as continuous as possible by linking them up on the under side of the deck, by an intercostal girder on each side between hatches and machinery openings and deck-houses.



Beams of special strength are fitted at the ends of all hatches, and upon all side arched webs (see figs. 59 and 60 A). All beam knees are three times the depth of the beams upon which they come. Single pillars are fitted to every beam in the holds (4 ft. 2 in. apart) excepting in way of hatches, where never more than two are fitted to each side. The centre line pillars are slightly reeled, giving a 3 in. space for the support of grain shifting boards. In the shelter deck 'tween decks the pillars are similarly spaced, and are situated so as to be in a direct vertical line with those below.

The six watertight transverse bulkheads are stiffened vertically with large bulb angles 9 in. × 3½ in. × $\frac{11}{20}$ in., spaced 30 in. apart. In Nos. 2, 3, 4, and 5 bulkheads, the vertical stiffeners are bracketed to the inner bottom plating, while, in addition, they have a semi-box beam on the same side as the vertical stiffeners, leaving the other side of the bulkhead absolutely clear for caulking. The collision bulkhead also is stiffened vertically on the fore side with large bulb angles 8 in. × 3 in. × $\frac{11}{20}$ in., spaced 30 in. apart, and horizontally on the fore side also by a plated flat forming the top of the fore peak tank, and two semi-box beams in line with the lower continuous side stringer and the panting stringer. The vertical stiffeners, which of necessity are interrupted at the plated flat, are efficiently bracketed thereto on both sides, and also at their upper extremity. The after side is thus quite clear for caulking. The aftermost bulkhead is similarly stiffened with bulb angles on the after side between the flat-topped after tunnel recess and the upper deck, to both of which the stiffeners are bracketed, while the only practicable position for the required semi-box beam is on the fore side as shown. This bulkhead is caulked on the fore side.

Every 4th and 5th frame (whether arched web frames, or brackets upon the deep bulb angle frames) is doubly secured to the inner bottom plating by the gusset plates shown on the midship section, fig. 60 A.

STRINGERLESS TYPE OF CARGO STEAMER.

One of the most striking innovations in recent years in the construction of cargo-carrying vessels is the type represented by four ships built recently under the survey, and to the highest class, of the British Corporation for the Survey and Registry of Shipping. The dimensions are:—

Length B.P., 410 ft. 0 in.
Breadth moulded, 52 ft. 6 in.
Depth „ 32 ft. 6 in.

These vessels have two steel decks continuous all fore and aft, but up to the height of the first steel deck, side stringers have altogether disappeared, as shown in the midship section, fig. 61. This is indeed a startling change, and, under the ban of preconceived ideas and custom, it at first is not easy to believe that the change is altogether an advance in the science and art of shipbuilding. But two things are certain: first, that Mr King, the Chief Surveyor to the British Corporation, who carries the chief responsibility for the new system, is disturbed by no doubts in his own mind as to the superiority of this method; and second, that vessels of the dimensions given above are now at sea carrying the loads for which they were designed without signs of weakness. The latter is the best known practical test of a vessel's structural efficiency.

While, however, the side stringers have disappeared, it must not be imagined that these ships have been robbed of this amount of structural material, for the weight of steel in one of these vessels is practically the same as for one of similar size and of usual construction.

What is really claimed for this type of vessel is, that greater economy in construction is secured by a reduction in the number of parts fitted, and that a stronger ship for a similar weight of material is obtained than with the more complicated ordinary methods of shipbuilding.

What has taken place, therefore, is simply this: that a redistribution of the material has been made, and that instead of the total strength of the ship girder being made up by the usual number of complicated parts, some of the less essential of those parts have been dispensed with entirely, and the more important and vital parts have been increased in strength by additions to their scantlings. By this method a large amount of riveting is saved, not merely from a cost point of view, but from an efficiency standpoint.

Description.—The frames and beams are of extra heavy section. The frames are 12 in. channels, spaced 26 in. apart, with 4 in. fore and aft flanges; the flange taking the shell plating having extra close pitch of rivets. After being accustomed to seeing the inner edges or flanges of the frames abundantly tied and supported by fore and aft stringers, it is not easy to get rid of the idea of the possibility of "tripping" (*i.e.* fore and aft working of the inner flanges of the frames owing to unsupported leverage from the shell plating). But, on the other hand, when it is recognised that the frames are riveted to the shell by 4 in. flanges, which are one-third of the depth of the frame, the element of doubt begins to dissipate. The brackets to the tank side are of unusual depth. These not only afford great support to the channel frame bottoms, but by keeping the latter above the round of the bilge, it is possible to put all the "sett" (slight bend to form the tumble-home) on the frames with the squeezers.

The frames are well supported again at the two decks by the deep knees. These knees are tapered towards the frame on the upper edge so as to get as many rivets as reasonably possible through the frame.

The shell plating is considerably increased in thickness above the normal.

To sum up, the elements of transverse and longitudinal strength are

stronger and stiffer, while the capacity to resist sheering stresses is increased.

In the particular ship illustrated there was no rise of floor, thereby somewhat simplifying the construction of the double bottom, the tank being perfectly rectangular over the midship body. The hold pillars were of large tube type, permitting of wide spacing.

Steamers for carrying Oil in Bulk.

The great development which has taken place in comparatively recent years in the exportation of petroleum from Black Sea and American ports, as naturally led shipowners to consider what was the most economical way in which this cargo could be carried, and notwithstanding the preudice and suspicion of danger which first existed in the minds of many nterested shipowners and others against the carrying of oil in bulk, as well as the difficulties which presented themselves, yet the great advantage over that of carrying oil in cases and in barrels led to the experiment being made. The first ship in which oil was carried in bulk was fitted out at the shipyard of Messrs Craggs & Co., of Middlesbrough. The vessel was an ordinary cargo steamer, into the holds of which huge oil-tight tanks were fitted, shaped to the form of the vessel. In these tanks the oil was carried. Since then, a large number of vessels have been specially built to engage in this trade, and great developments have been made in the construction and adaptation of ships for this purpose, due in no small measure to the Bureau Veritas Classification Society, whose experience was probably unequalled in the early days of tank steamers.

Figs. 62 and 63 are profile illustrations of two modern oil steamers built by Messrs Armstrong, Whitworth & Co., of Newcastle-on-Tyne, who have earned a great reputation in building this class of vessel. Fig. 64 is a midship section showing the disposition of the material in the construction. Before briefly observing the principal features in the arrangement and construction of oil steamers, a few points especially peculiar to vessels engaged in carrying oil in bulk, which affect the design to a considerable extent, and need to be well remembered in the process of construction, may be first noted.

1st. The gas which arises from petroleum, especially crude oil, in combination with the atmosphere becomes highly explosive at a certain point.

2nd. If the temperature of the oil is increased, it is subject to expansion.

3rd. While, in an ordinary cargo vessel, the cargo bears directly upon the transverse and longitudinal framing, the weight chiefly being taken by the floors, in a modern oil steamer the oil extends out to the outside shell plating, and, like all fluids, exerts its pressure square to the surface against which it comes into contact.

In addition to this, there is the increased pressure due to the inertia of the cargo itself, as the vessel rises and falls in her pitching movements, and, to a less extent, in rolling.

4th. With liquid cargoes, like oil or water carried in bulk, there is always a certain amount of danger in the process of filling up the tanks, if the vessel is deficient in stability. Evidently, should the vessel, through lack of metacentric height in any condition, take a list, the free surface of the liquid in a partially filled tank may tend only to increase the heeling, for the more the vessel inclines the more will the liquid shift.

From the principal points just enumerated, it follows that *oil-tightness*, *structural strength*, and *stability* are of the utmost importance in vessels carrying liquid cargoes in bulk, and suitable provision must be made for the expansion of the oil. Nothing is more essential than that the riveting be most efficiently performed, and the workmanship generally of the very highest character. Bad riveting spells doom to an oil steamer, for one can easily imagine, taking one aspect of the danger alone, what terrible results might accrue (as past experience has proved) owing to leaky bulkheads and the oil or gases finding their way into the engine and boiler compartments. More disasters from explosion and fire have happened to oil steamers than from any other cause. A loose rivet should never be caulked, but the rivet removed, and the hole re-riveted. It is also necessary, in order to obtain and maintain oil-tightness, that the very best form of rivet should be adopted. Two kinds of rivets have proved very satisfactory for oil-tight work, the pan-head rivet with the swollen neck, and the plug-head rivet (see fig. 76). In adopting either of these, the plating ought to be countersunk, so as to better receive the swelled neck. The drift punch must be rigorously forbidden. Blind holes should be rimed fair and not torn open, as so often is done with the drift punch. The spacing of rivets for oil-tight work should never exceed 3 to 3½ diameters of the rivet.

In all vessels carrying liquid cargoes in bulk in the hold spaces, the strain upon shell plating and bulkheads is very great, owing to the pressure of the liquid increased by the inertia of the cargo when pitching and rolling. The bulkheads should therefore be amply stiffened and supported. The rivets through the flanges of the frames connecting the shell, which largely bear the strain due to pressure on the shell plating, should be spaced not more than six diameters apart.

In all hold spaces in which liquid cargoes are to be carried, the middle line bulkhead should be fitted all fore and aft through such spaces, extending from the keel to the deck forming the crown of the tank, or to the top of the expansion trunk. This bulkhead should be strictly oil- and water-tight. It is valuable because it contributes strength and unites and supports the deck and bottom plating, but it is most valuable from a stability point of view, its principal function being to minimise the shifting of cargo in the event of the vessel taking a slight list in the process of filling up the tanks. It ought never to be required for this purpose when the vessel is at sea, for all tanks ought to be completely filled before proceeding upon any sea voyage, however short it may be. To proceed to sea with an oil or a water-ballast tank only partially filled is to invite disaster, for such display of ignorance has not infrequently resulted in bulkheads being torn down and other extensive damage wrought. A longitudinal bulkhead also reduces the inertia of the cargo when rolling in a seaway. Long hold spaces in a fore and aft direction are most undesirable in any vessel carrying liquid cargo in bulk, because of the rapidity with which such cargoes shift should the tank not be completely filled, and the great inertia which huge volumes of such cargo possess. Such danger as described can easily be imagined if by any chance a vessel began to pitch in a seaway, with a very long hold only partially filled. Under such circumstances, for any bulkhead to bear the strain would be practically impossible, not to mention the additional danger which would arise from vastly increased change of trim and heavy diving which would undoubtedly ensue. Transverse bulkheads should therefore never be spaced at greater intervals than between 24 and 28 ft., and should be thoroughly oil- and water-tight. Vessels carrying liquid cargoes are especially subject to severe racking stresses, and strength to encounter such is largely provided by these numerous transverse bulkheads.

As before stated, all bulkheads, both transverse and longitudinal, should be very strong and well supported. Oil steamers should possess a reasonable metacentric height at every intermediate draught between the light and load lines which is passed through as the tanks are being filled. In the fully loaded condition, from 1 to 2 ft. should prove a satisfactory metacentric height in vessels of usual proportions. No class of cargo vessel is so easy to manipulate in the process of designing, in order to arrive at a desired condition of stability, as the bulk oil-carrying steamer, because in no other cargo vessel is the seagoing condition so constant.

In order to provide for the increased bulk in the event of expansion taking place, a trunk-way is fitted in the 'tween decks continuously all fore and aft over the main hold tanks. This is shown clearly in fig. 64. The transverse bulkheads must extend to the top of the expansion trunk.

In order to minimise the danger of leakage, so as to prevent either oil or gas finding its way either into the engine and boiler space or cross bunkers, or into any hold space used for other purposes than carrying oil, double bulkheads are fitted at a distance of not less than two frame spaces apart. Both these bulkheads are oil-tight, and extend from side to side, and from the keel to the top of the expansion trunk. In fig. 62, where the engines and boilers are situated at the after end of the vessel, the two oil-tight bulkheads just mentioned are shown between the cross bunker at the fore end of the boiler room and the aftermost oil tank. The space between these bulkheads is called a *coffer-dam*. In this vessel, as the whole compartment abaft of the collision bulkhead is used for general cargo, a coffer-dam is again found between this compartment and the foremost oil tank. It is most unusual to carry oil in the endmost compartments of any steamer. Indeed, for vessels passing through the Suez Canal, this is strictly enforced; and another regulation is that the coffer-dams be filled with water to their utmost extent, when carrying oil in bulk. This, it is hoped, will form an effective barrier against any oil finding its way through the coffer-dam. But even with these precautions, owing to bad riveting, or excessive straining of the bulkheads arising from defective stiffening, oil and gas have been known to percolate through the coffer-dam bulkheads into cross bunkers and into engine and boiler rooms. When this has happened in vessels where it has been customary to fill the coffer-dams with water, this serious condition of affairs has generally been brought about by part of the water leaking from the coffer-dam, its place having been taken by oil which has leaked into the coffer-dam and floated on the water, and eventually found its way into the adjoining spaces. Hence, that these coffer-dams be frequently inspected during the voyage, and their condition ascertained, is most essential. If oil is found in the space, it should be drawn off. Ample ventilation to the coffer-dams is extremely necessary. Some owners prefer to keep the coffer-dams empty, and by frequent inspection the ship's officers are kept cognisant of their condition. In the event of oil having found its way into the space, it is immediately pumped back into the main tank. In this case again, thorough ventilation is essential. Fig. 65 shows an enlarged view of a coffer-dam in a vessel where the engines are situated amidships. It will be seen in the coffer-dam diagram that the strength of its two bulkheads is united and great additional support given by means of the diaphragm plates shown. In a transverse direction, these diaphragm plates are spaced about 3 ft. apart. In fig. 63, which shows the engines and boilers amidships, it will be observed that a coffer-dam is situated at the aft end of the engine room, another at the fore end of the cross bunker forward of the boiler room, another at the fore end of the foremost tank, and another at the after end of the aftermost tank. While there is much to be said in favour of placing the engines and boilers amidships, the great advantage of placing them at the after end is that they are more entirely shut off from the oil tanks, and the danger rising from leakage minimised. To ensure safety, the donkey boiler and galley must be thoroughly isolated from the oil tanks.

The transverse frames should preferably be of bulb angle, or channel, or Z bars, instead of the ordinary frame and reverse bars. This reduces the riveting and secures greater transverse strength, which is a highly important factor in bulk oil-carrying vessels. In two decked vessels, the second deck forms the crown of the main oil tanks. It should therefore be a thoroughly oil-tight flat. To secure this most effectively, all the frames are usually cut in way of this deck, and the deck plating carried without a break right out to the shell of the vessel, to which it is connected by a continuous angle bar. This is clearly shown in the midship section, fig. 64. The frames in the 'tween decks are connected to the beams at their upper extremity, and to the deck at the lower extremity, by means of bracket knees. The ex-

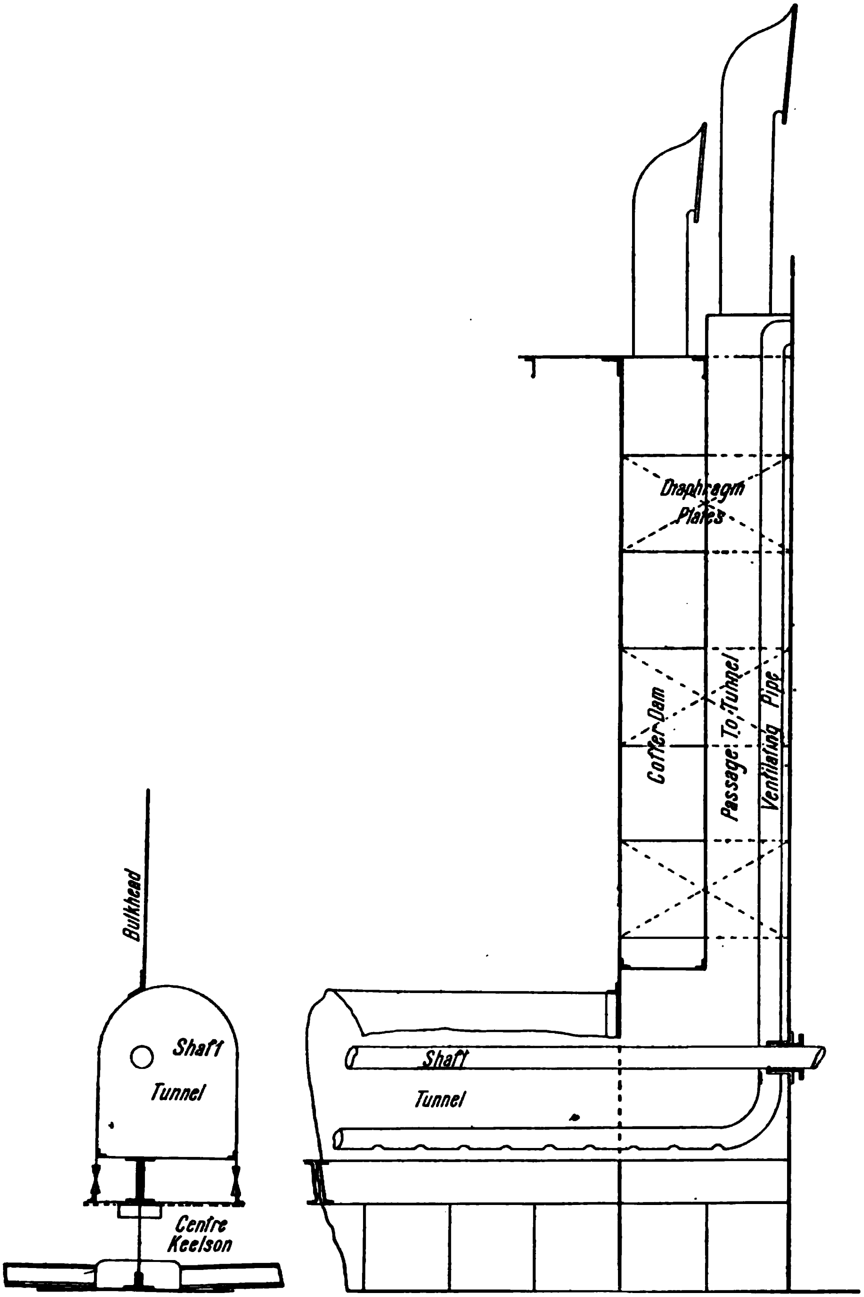


FIG. 65.—Enlarged View of Coffer-dam, showing Diaphragm Plates, Trunk-way to Tunnel, and Ventilating Pipe.

pansion trunk (see fig. 64) is fitted all fore and aft in the 'tween decks, and its sides are supported by webs of plating at intervals as shown. All the oil hatches on the upper deck must be strongly constructed and oil-tight. The spaces in the 'tween decks at the sides of the expansion trunks are used as bunkers. The plan of the upper deck (fig. 62) shows the arrangement of all the oil and bunker hatches, and the plan of the second deck (fig. 62) shows the continuous expansion trunk-way and the longitudinal and transverse bulkheads, including the coffer-dam bulkheads. Where lines indicating bulkheads are shown in full, they extend to the upper deck; and where such parts of them are dotted, they terminate at the second deck.

In oil vessels of a depth such as to require three tiers of beams, the lower deck is usually dispensed with, as shown in the midship section, fig. 64, compensation being made by means of web frames and web stringers. Two web frames are usually placed in each oil tank. An extra deep beam extends across the vessel at the head of each web frame, to which it is connected by a large plate knee, as dotted upon the midship section. The longitudinal bulkhead, which is oil-tight, extends from the keel plate to the top of the expansion trunk. The vertical stiffeners are of bulb angles one frame space apart, lapped on to the floor plates, and further connected to the floors and to a narrow width of deck plating through the expansion trunks by plate brackets. At intervals, deep web plate stiffeners are fitted. These are spaced to agree with the web frames on the ship's side, the bulkhead web plate stiffeners being bracketed to the deep plate beams which unite the heads of the web frames. They are also lapped on to and bracketed to the floor plates (see fig. 64). On the other side of the longitudinal bulkhead, channel plate horizontal stiffeners are fitted, spaced so as to be at the same distances above the keel as the web stringer plates.

The transverse bulkheads are continuous from side to side of the vessel. The longitudinal bulkheads are therefore fitted intercostally, as it were, between them.

The stiffening of the transverse bulkheads is very similar to that just described for the longitudinal bulkhead (see figs. 66 and 67). The vertical stiffeners, which are of bulb angles, are spaced about 2 ft. apart, and the horizontal channel plate stiffeners agree with the spacing of the web stringers and horizontal stiffeners in the longitudinal bulkhead.

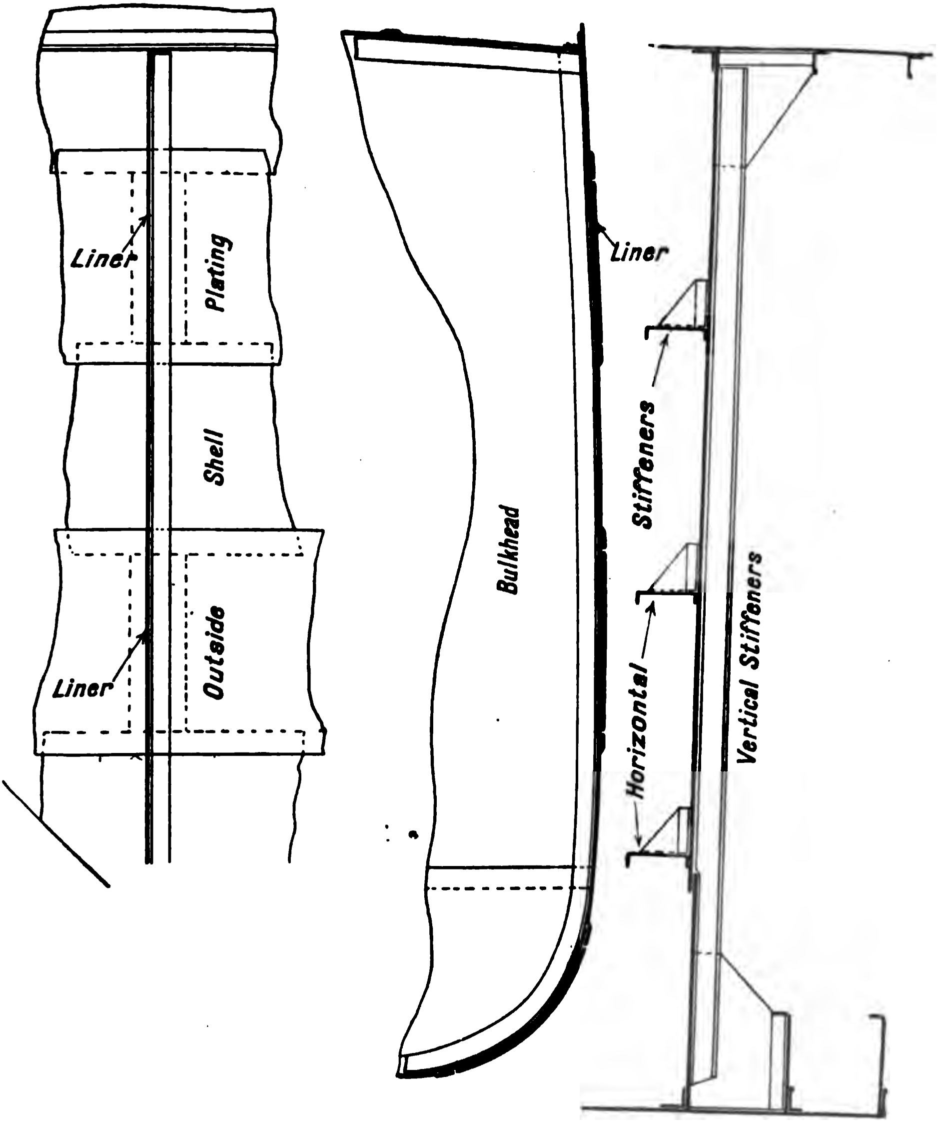
The vertical stiffeners are bracketed, top and bottom, as shown in figs. 66 and 67, and the horizontal stiffeners of both the transverse and longitudinal bulkheads are thoroughly united by large brackets, as shown in fig. 67.

Transverse bulkheads, exceeding 42 ft. in breadth, should have four vertical web plate stiffeners in addition to the longitudinal bulkhead, and where the breadth is less, two vertical webs, one on each side of the longitudinal bulkhead.

Attention is drawn to the splendid stiffening which is afforded to the

FIG. 66.

TRANSVERSE BULKHEADS.



oil tanks in the arrangement just described by having all horizontal stiffeners and web stringers practically in the same horizontal plane, each tank being circumscribed by this web system of stiffening.

As the oil-tightness, particularly of the transverse bulkheads, is of such paramount importance, it is usual to cut all stringers and keelsons which would pass through this bulkhead, and preserve the continuity of strength of these important longitudinal girders by large bracket plates, as shown in fig. 68. Sometimes, however, the side stringers are carried uninterruptedly through the transverse bulkheads, as in fig. 67. In this case, most efficient angle collars have to be fitted metal to metal to preserve watertightness.

The connection of all seams and butts in the plating of bulkheads should be by means of laps, double riveted throughout. A most important point in all oil-tight work is to avoid three-ply riveting, as the tightness of such is not nearly so reliable. Thus, that the connection of the transverse bulkheads to the shell plating and deck and to the longitudinal bulkheads be by means of large single angle bars, with flanges broad enough to take two rows of zigzag riveting, is strongly recommended (see figs. 66, 67, 68, 69, and 70).

The bulkhead liners fitted to alternate strakes of shell plating are usually of sufficient width, so as to get one row of rivets on each side of the bulkhead shell bar. This, it is found, is more easily caulked and made watertight (see fig. 70). When the shell plating is flanged, as shown in the midship section, fig. 64, each strake of shell plating therefore bearing close upon the frames, and no packing being required, the bulkhead liners may be fitted on the outside of alternate strakes of the shell plating (see fig. 66); but more usually the liners are dispensed with, and, by making the bulkhead shell bar of extra thickness, a wider spacing of shell rivets is obtained, so as to weaken the shell as little as possible.

That the bulkheads be caulked upon both sides is strongly recommended. In order to ensure thorough tightness at all connections, this should be secured by the surfaces of the metal bearing hard upon each other. Felt packing should, under all circumstances, be avoided in oil-tight work, and white lead as far as possible. The latter, however, cannot always be entirely dispensed with, white lead injections being at times necessary.

The seams of the shell strakes should be double riveted, and the butts preferably overlapped and treble riveted with three complete rows of rivets. Two rivets should pass through the seams upon every frame instead of the single rivet in ordinary cargo steamers, in order to ensure oil-tightness. If the butts are not lapped, they should be connected by double butt straps treble riveted in way of all oil-tanks. When the engines are situated amidships, as in fig. 63, the shaft tunnel is entered by means of an oil-tight trunk-way from the upper deck at each end of the tunnel. In fig. 63 this trunk-way passes through the coffer-dam at each end of the tunnel, and is itself independently oil-tight. An enlarged view of the fore trunk-way is shown in fig. 65. Needless to say, the tunnel is thoroughly oil- and gas-tight. It should, however, be well ventilated by cowl ventilators into each trunk-way.

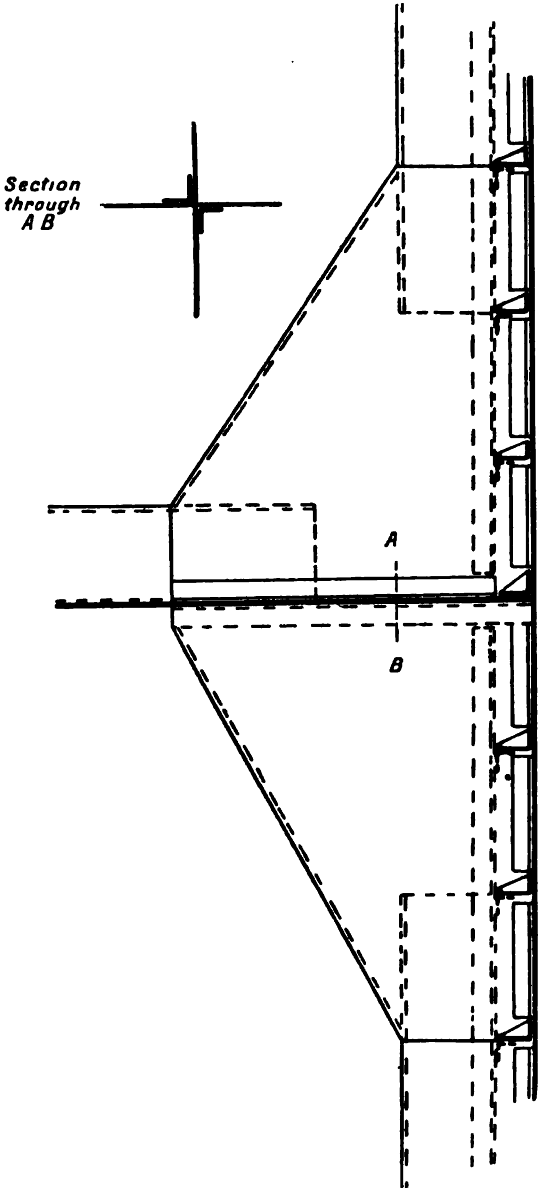


Fig. 68.—Showing a Side Stringer cut and bracketed to a Bulkhead (oil steamer.)

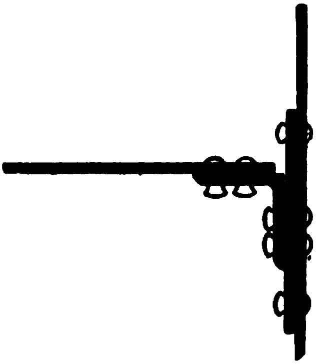


Fig. 69.—Showing Bulkhead Liner and Angle Connection to Shell.

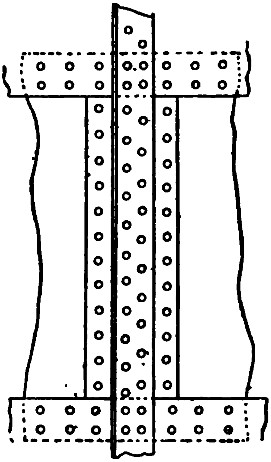


Fig. 70.—Bulkhead Liner.

The gases which are emitted from the oil are of greater specific gravity than the atmosphere; they are, therefore, apt to lodge about the lowermost recesses of all spaces into which they enter. A system of drawing off any such gases, and assisting in the ventilation of the tunnel, is shown in fig. 65, where a large perforated pipe passes along the tunnel and up the trunk-way to a fan which acts as a suction.

Even when all the oil has been pumped out of the oil tanks, great danger still exists for the reason just mentioned, viz., that the heavy and inflammable gases hang about the bottom of these spaces. To rid the tanks of these objectionable and dangerous vapours, several means are used, the chief being to blow out the gases by means of steam injections, and to draw off the gases by using the oil suction pipes with a fan. Steam injections are sometimes used when necessary in the tunnel. Ample ventilation should be provided to all oil tanks. In order that the oil may readily reach the pump suctions, sufficient limber holes should be fitted through floors and side intercostal plates, but on no account through the middle line bulkhead.

Oil vessels have been built with an inner skin, but there is little to recommend this system, the space between the inner and outer skins being a harbourage for gas. When such a system is adopted, the importance of fully ventilating these spaces is obvious.

Water-ballast Arrangements.

It is not intended in this chapter to enumerate and discuss the reasons and necessity for arrangements in the modern cargo steamer for the carriage of water for ballasting purposes. This has already been done in *Know Your Own Ship*. Suffice it to say, as every seaman knows, that, in these days of fluctuating freights, large vessels frequently make long over-sea voyages without cargo. And with the full bilge and small rise of floor so commonly given to present-day steamers, and remembering, too, the great increase which has taken place in the dimensions of such vessels, it follows that the draught in light condition is greatly less in proportion, than it used to be for the finer-formed and smaller-sized cargo vessels of say twenty or thirty years ago. All this enhances the necessity for ballast when in a light condition, and as water has been found to be the most economical ballast that can be carried in steamers, it is proposed to illustrate the principal arrangements for the carriage of water ballast.

M'Intyre Double-Bottom Tanks.—The first occasions upon which water ballast was introduced into vessels were to enable colliers carrying coal from the Tyne to London to make the return voyage without the necessity and expense of loading, and at the end of the return voyage discharging, dry ballast. The necessary alterations in the first vessels fitted for this purpose were carried out by Messrs. Palmer & Co., of Jarrow-on-Tyne. In the system then adopted, the water ballast was carried along the bottom and contained between the outer and an inner bottom, which latter was laid upon fore and aft girders standing upon the ordinary floors, and made watertight by being connected to the outside plating.* Fig. 50 illustrates the midship section of a vessel fitted with the modern arrangement of such a double bottom tank, in some of the smaller details the construction having been slightly modified from what it was originally. For instance, in some of the earlier cases, the tank top plating was carried in a horizontal, or almost horizontal, direction from the top of the centre keelson right out to the bilge or shell plating, and made watertight at each of its side extremities by being connected to the shell by means of angle collars. Another system of making this connection is by flanging the tank side or margin plate similarly to the system illustrated in fig. 50, so as to meet the bilge plating at right angles. The watertightness is here again secured, and the connection made, by means of angle collars. In both of these cases the reverse frames are cut at the tank side, and compensation made by doubling the frame bar (which is continuous from keel to gunwale) for about 3 ft. This greatly facilitates the fitting of the watertight collars.

But the method now most usually adopted for the connection of the tank side to the shell plating is that shown in fig. 50, where the tank side or margin plate is arranged to meet the shell at right angles. In this case the main frames are cut at the tank side and the margin plate is connected to the shell by a continuous angle bar. This is probably the simplest way of ensuring the watertightness of the tank. The efficiency and continuity of the transverse framing is effected by connecting the frame legs outside the tank to the tank side plating by means of large bracket plates or tank knees. Hence the tank side plate must have sufficient breadth, so as to get a sufficient number of rivets through to ensure a good connection. Similarly, on the inside of the tank, large brackets connect the floors to the tank side plating.

Cellular Double-Bottom Tanks.—However, since the inauguration of the M'Intyre tank, a very considerable development has taken place, and now a type of tank which is more embodied in the main hull of the vessel has come to be extensively adopted, though not to entirely supersede the M'Intyre tank. This tank is that illustrated in figs. 7, 13, and 49, etc., and is known as the cellular double-bottom water-ballast tank. In the M'Intyre double-bottom tank the floors are upon every frame all fore and aft, and in the earliest form of this tank the ends of the floors were turned up the bilge in the usual way. But in later M'Intyre tanks, the floors inside the tank have been carried in a horizontal line from the centre keelson to the intersection with the frame or tank side, and strengthened at their narrow outward ends by bracket plates fitted to the tank side (see fig. 50). If desired, this tank may extend over only part of the length of the vessel, the remainder of the bottom being of the usual construction. The tank is commonly dispensed with under the engines, and especially

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* This is known as the M'Intyre tank, as the idea originated with Mr John M'Intyre, the manager at that time of Palmer's shipyard.

under the boilers, on account of the rapid corrosion, due to damp heat, which is known to take place under the boilers.

In the cellular double-bottom form of construction, the centre keelson, or centre through-plate, is continuous fore and aft, with two large continuous angles on its upper and lower edges. The floors in mercantile steamers are usually solid from the centre through-plate to the tank margin plate, lightened by manholes as shown in figs. 7, 13, 49, etc., etc., which manholes are also the only means of passage through the tank. The inner bottom plating is laid on the top of these floors, and the margin plate is arranged at the tank side so as to meet the shell plating practically at right angles. The floor plates are stiffened and prevented from buckling by fitting one or more intercostal girders, according to the size of the vessel, which are connected to the inner and outer bottom plating and to the floor plates by angle bars (see fig. 13). Or the angles taking the inner and outer bottom may be dispensed with by flanging the plates (see figs. 40, 42 to 47).

Where, however, the maximum longitudinal strength is desired, these side girders are commonly fitted continuous all fore and aft, the floor plates and reverse bars inside the tank between them, therefore, being intercostal owing to the top angles on the side girders being continuous. On account of the depth and strength of the floor plates, the large frame bar, such as is fitted outside the tank, is not required, and, as shown in fig. 13, a smaller bar, whose flanges are of about the size of the smaller flange of the ordinary frame, is used. As shown in fig. 13, the reverse bar is fitted, as in the case of ordinary floors, on the opposite side of the floor plate to the frame bar. The tank side is made watertight by fitting a continuous bar on the lower outside edge of the margin plate, so as to bear hard against the bilge shell plating to which it is riveted. Both frames and reverse bars are severed at the tank side, this being necessary in order to simplify the rendering of the inner bottom watertight. However, as the transverse strength must be uninterruptedly maintained, the frame legs are attached to the tank side by large bracket plates carried well up the bilge. These are connected to the tank side by double angle bars for at least half the length in large vessels. It may be noted that the reverse bars in the double bottom are doubled under the engines and boilers, where special rigidity is required, and for the same reason, additional intercostal side girders are fitted. The cellular double-bottom ballast tank is usually divided into numerous separate watertight compartments, not only for the purpose of subdivision in the event of the perforation of the outside plating, but in order to ballast the vessel so as to obtain a desired condition of trim.

Fig. 71 shows a modification in the construction of the cellular double-bottom tank, as previously shown.

In this system, the longitudinal side girders are more numerous, and the floor plates are only solid upon alternate frames. On the intermediate frames, brackets are fitted to the centre through-plate and the tank side.

The connection of the tank side to the frame legs is identical with that previously described for the more ordinary cellular double bottom, brackets being fitted to every frame. A point to be noted in this form of construction is, that whereas in Board of Trade *standard* vessels with cellular double bottoms having solid floors to every frame, when the shell plating in way of the double bottom is $\frac{11}{20}$ths or more in thickness, a reduction of $\frac{1}{20}$th is permitted; no such reduction is allowed where the floors are not solid upon every frame. All double-bottom tanks are entered by means of manholes in the tank top plating, which should be sufficiently numerous and situated in such positions as will give the easiest access to every cell or compartment in the tank. At least one manhole should therefore be cut in every solid floor plate between the longitudinal girders, whether intercostal or continuous, and, at intervals, manholes should be cut in the side girders also; but as the centre through-plate is a most important item in the longitudinal strength of the vessel, upon no account should it be perforated by manholes, as this would seriously interrupt the continuity of its strength. Indeed, in some vessels the centre through-plate is perfectly watertight, for part, if not for its whole length.

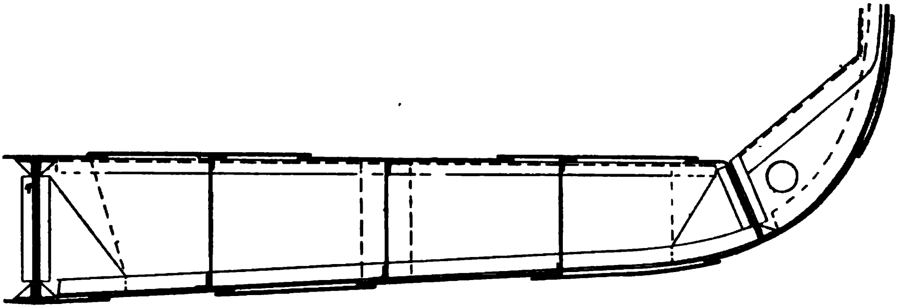


FIG. 71.—Cellular Double Bottom, constructed with Solid Floors upon alternate frames, and Bracket Plates upon intermediate frames, as shown in this sketch.

Fore and After Peak Tanks (see figs. 11, 12, and 14, etc.).—As the lower spaces on the fore side of the collision bulkhead, and on the after side of the aftermost bulkhead, are both inconvenient and unsuited for the carriage of cargo, and ill adapted even for ship stores, it has become common in steamers to use one or both of these spaces in which to carry water for trimming purposes. It is scarcely correct to call them ballast tanks, for their capacity is comparatively so small that the weight of water they contain produces very slight increase in the mean draught, but the filling of one of them produces considerable change in the trim, situated as they are so far from the centre of gravity of the ship. Hence, in a light condition, the filling of the after-peak tank may considerably contribute to the immersion of the propeller, though there follows the natural objectionable result of the bow being lifted correspondingly out of the water. The fact must not be overlooked, that when these tanks are made very large, containing, as they do in some cases, over 100 tons of water, they are liable to produce straining when the ship pitches in a seaway in the light condition. In any case, the bulkhead separating these spaces from the holds will be watertight, though, when the peaks are intended for water ballast, these bulkheads should be especially strengthened. In addition, the deck forming the top of such a tank must also be watertight. It must therefore be constructed of iron or steel, and if the space complies with the conditions necessary for its deduction from the British tonnage, it must be entered only by means of a manhole in the deck plating. As there is always the danger of these tanks being only partially filled (it should be rigorously enforced that these and all water-ballast tanks be kept full at sea), wash plates are fitted down the middle of their length (see fig. 14).

Deep Midship Tanks.—Especially in recent years has the practice been adopted of constructing one or more deep water-ballast tanks somewhere in the middle length of the vessel, usually at one or both ends of the engine and boiler space. Fig. 53 illustrates the position of these tanks. They are in reality hold spaces so constructed as to be available for the carriage of cargo when required, and water as ballast when in a light condition. They are bounded on each end by watertight bulkheads specially strengthened, and are enclosed on the top by a watertight iron or steel deck or flat. When these tanks extend from side to side of the vessel, a watertight bulkhead must be fitted down the middle of the tank in a fore and aft direction. These tanks are entered by means of small hatchways through the watertight deck, which hatchways are themselves made watertight by means of an iron or steel plate bolted on to their coamings. The steamer in fig. 14 has a deep water-ballast tank at the after end of the engine room.

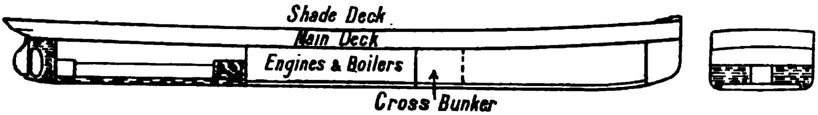


Fig. 72.—Illustrating Side Water-ballast Tanks in shallow high-speed Passenger Steamers.

Side Deep Tanks.—Instead of carrying midship deep tanks from side to side of the vessel, they are sometimes fitted only in the wings (see fig. 72). Carrying less water than they would do if fitted from side to side, they do not produce as much increase of immersion; but from a theoretical point of view they possess a decided advantage in easing the vessel in her rolling motions, and producing a steadier ship. They are therefore better adapted for shallow high-speed passenger vessels, which carry little or no cargo. In such cases, an ordinary manhole is sufficient as a means of entrance; but where it is desired to use these tanks for other purposes than water ballast,—bunker coal, stores, or cargo,—watertight hatches may be fitted.

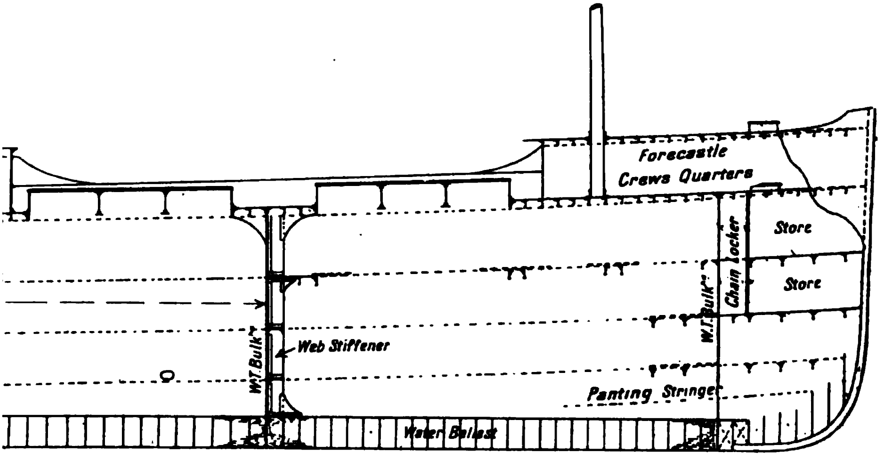
M'Glashan's Patent Ballast System.—The inventor of this system of ballasting, realizing the unsuitability of the ordinary double bottom tank as a sole means of ballasting, has devised the system illustrated in figs. 73, 74, and 75, whereby, in addition to a cellular double bottom which is of the ordinary mode of construction, side tanks are built into the vessel's structure on the sides over the middle length. The extent and construction of these tanks are fully illustrated in the profile, midship section, and deck plans, together with the notes given upon the same, in figs. 73, 74, and 75.

In the vessel we illustrate, the side tanks extend from the cellular double-bottom tank margin plate to the upper deck. The breadth of each side tank is about 27 in., and they extend in a fore and aft direction over at least one-half the vessel's length amidships. The framing in the way of these tanks is somewhat similar to the web frame system, solid plate web frames, lightened by manholes, being fitted to the alternate frames. The longitudinal framing on the vessel's sides is composed of web stringer plates fitted intercostally between the web frames. The upper deck beam knees are riveted to the inner wall of tank plating by means of angle bars. In addition to the increased and improved facility for the carriage of water ballast in this vessel, several other advantages are gained.

1st. Over the midship half length, the vessel possesses an inner skin from gunwale to gunwale. This may prove of immense value to the safety of the ship in the event of the outer skin being perforated, owing to collision or other cause.

2nd. The additional strength which is manifestly given to the structure by two vertical skins of plating on each side, supported and united as they are by the transverse and longitudinal web framing, fully compensates for the omission of the lower deck beams in the way of these tanks. This, in its turn, improves the conditions for stowage of cargo. The capacity of the hold space is somewhat reduced, but it should be remembered that the tonnage also suffers reduction, as it is only measured to the inner tank side plating; and it is also noteworthy that a vessel built on the ordinary web frame system suffers from broken stowage of cargo, owing to the web framing, which projects 15 or 18 in. from the shell plating into the hold. The construction of the vessel forward and abaft of the side tanks is of the usual kind. A most important point in such tanks as these is that free access be readily gained to every part of the interior; hence manholes fitted with watertight plate covers are cut at intervals through the deck plating (see plan, fig. 74). And in order that access may be obtained from the hold or machinery space, manholes with similar watertight covers are cut through the inner wall of tank side plating. In addition, as previously pointed out, the transverse web plates are lightened by numerous manholes which facilitate the means of passage from one part of the tank to another, and the longitudinal web stringers also have manholes cut through them for a similar reason. This is absolutely

AST TANKS.


Forecastle
Crews Quarters
Store
Store
Chain Locker
W.T. Bulkᵈ
Web Stiffener
W.T. Bulkᵈ
Panting Stringer
Water Ballast

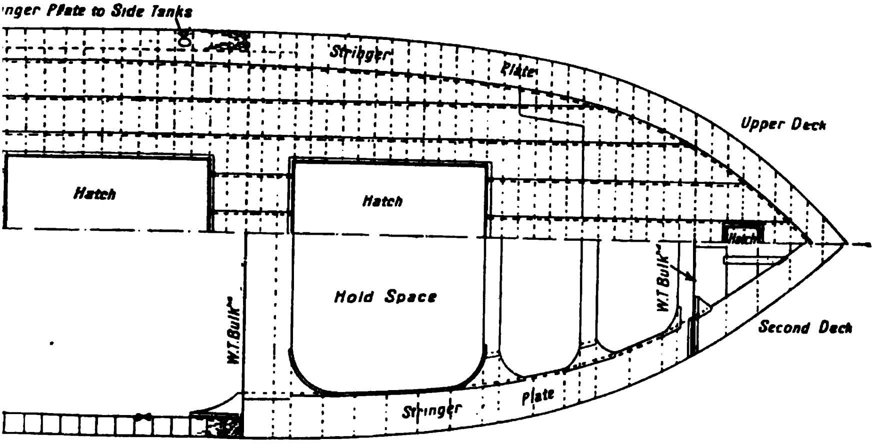
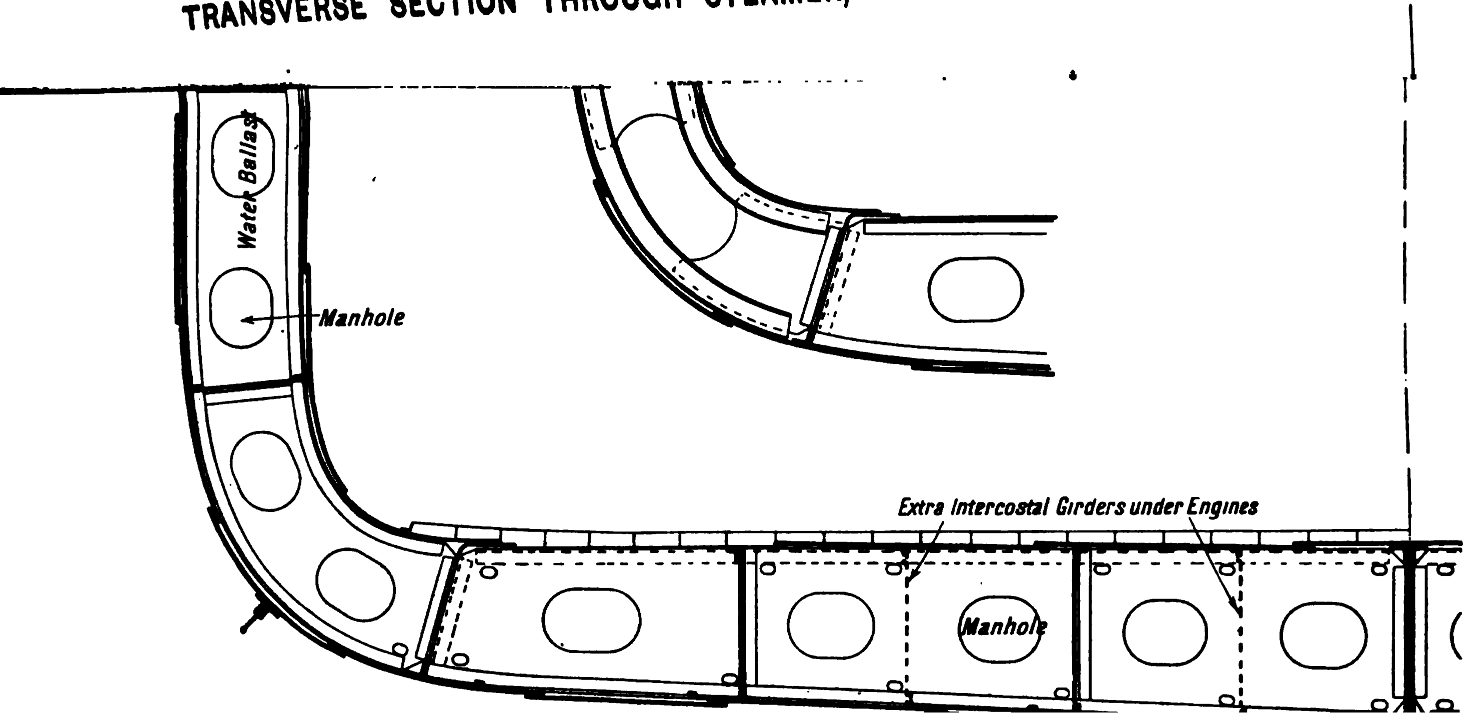

nger Plate to Side Tanks
Stringer
Plate
Upper Deck
Hatch
Hatch
Hatch
Hold Space
W.T. Bulkᵈ
W.T. Bulkᵈ
Second Deck
Stringer
Plate

FIG. 75.

TRANSVERSE SECTION THROUGH STEAMER, WITH SIDE WATER-BALLAST TANKS



essential in order that the tanks may be frequently, and as easily as possible, examined inside, and measures taken for their maintenance. In other respects, these vessels are similar to an ordinary cargo or passenger steamer.

The foregoing are the principal arrangements for water ballast in use at the present day. See also the special arrangement of upper side water-ballast tanks fitted to the "Cantilever Framed Self-trimming Steamer," page 78, and figs. 51 and 52. Also see special double-bottom water-ballast tank, illustrated in fig. 47, and described on page 73.

By the Merchant Shipping Bill which came into force in June 1907, *all bona-fide* water-ballast spaces, entered only by means of manholes of ordinary size, may be deducted from the gross tonnage on application being made to the Board of Trade. Every encouragement is therefore given to the efficient ballasting of sea-going vessels.

CHAPTER IV.

DETAILS OF CONSTRUCTION.

Rivets and Riveting—Butt Straps and Butt Laps—Keel Blocks and Launching Ways—Frames, Reverse Frames, and Floors—Beams—Pillars--Keelsons and Stringers—Bulkheads—Decks—Outside Shell Plating—Stern Frames and Rudders—Miscellaneous Details: Continuity of Strength, Engine and Boiler Space, Masts and Derricks, Panting, Hatches, Deck Houses, Poop and Bridge Front Bulkheads, Tunnels and Casings, Breast Hooks, Bilge Keels—Ventilation—Pumping—Launching.

Rivets and Riveting.

Quality of Riveting.—However carefully and perfectly the ship designer may determine the scantlings and arrange the material for the construction of a vessel, and however excellent may be the quality of the material, unless the innumerable plates and bars which go to make up the whole hull are most efficiently united to one another, it is impossible for the structure to develop its full strength without fracture at some of the most heavily strained connections supervening. Thus, while thoroughly efficient butt and edge connections should be arranged for, in so far as this is obtained by the amount of overlap or size of straps and number and diameter of rivets, everything depends entirely upon the quality of the riveting. Bad riveting utterly frustrates all ingenuity displayed in the design. In short, good workmanship is of the very highest importance in shipbuilding, and too great a stress cannot be laid upon this feature. Bad riveting has put many a shipowner to enormous expense, owing to the delay and cost of effecting repairs, and it is not altogether new to hear of huge ocean liners being put into dry dock in order to have their shell plating partially or entirely re-riveted. Carelessness in marking off and spacing rivet holes, and also in the operation of punching, invariably produces what are known as *blind* holes. These occur where the rivet holes, in overlapping plates or bars, are only partially over one another. A most objectionable practice under such circumstances is to force a passage for the rivet by means of a drift punch. Such a method should be rigorously forbidden. The proper way in which to clear away any obstruction caused by blindness should be by means of a rimer (a drill).

The tightness of rivets is tested by tapping the side of the rivet head with a small hammer, while two fingers of the other hand rest against the opposite side of the rivet head. An experienced workman can immediately detect a loose rivet. Loose rivets should never be caulked tight, but renewed and re-riveted. Sometimes, in testing a tank, or a water- or oil-tight compartment, a tight rivet may show signs of leakage; the only rivet which under such circumstances admits of being satisfactorily caulked watertight is the plug-head rivet, all others should be re-riveted. It is always more difficult to obtain tight work where the riveting is more than two-ply. Thus, as far as practicable, two-ply riveting should not be exceeded.

A number of different forms of rivets are used in the work of shipbuilding for watertight or oil-tight work. Rivets Nos. 6, 5, and 3 in fig. 76 cannot be surpassed for general efficiency. Nos. 6 and 5 are known as pan-head rivets, and No. 3 as the plug-head rivet. Pan-head rivets with snap points (No. 4) are not so reliable for watertight work.

Pan-head Rivets.—It will be observed that the pan-head rivet is of conical form just under the head, or, to use the common phrase, it has a swelled neck. The reason for this is that, when a plate or bar is being punched by a punching machine, the hole so punched is of conical form, increasing in diameter in the direction in which the punch passes; and as plates and bars are always punched from the faying surfaces (surfaces which have to lie against one another), the neck of the rivet is swelled so as to completely fill the hole in the plate or bar. In such places in the construction of the vessel where the work must be watertight, but the appearance of the rivet point is not of great importance, undoubtedly the best result can be obtained by beating down the point as shown in No. 6, fig. 76, especially if the rivet hole be countersunk

A countersunk rivet hole is one which has more taper than is produced simply by punching. It is formed by taking the punched plate or bar to a machine with a countersinking drill, which gives the bevel required.

In some parts of the ship structure, however, it is necessary that the rivet point be as near flush as possible with the plating, as, for instance, in the outside shell plating, steel or iron decks, and top of double-bottom tanks. In such cases, the rivet holes must be well countersunk and the rivets beaten down, any surplus material in the rivet being chipped off, and the point finally beaten so as to present a slightly full or concave appearance. This is shown in Nos. 2, 3, and 5, fig. 76. The pan-head rivet with the swollen neck and countersunk point can be highly recommended for great holding power. The heads are laid up with facility, while the rivets themselves are well adapted for entirely filling the holes. When the riveting has been satisfactorily performed, reliable water- or oil-tight results are assured.

Plug-head Rivets.—Plug-head rivets are also capable of producing highly satisfactory oil- or water-tight work, though greater care is requisite in performing the riveting. As shown in No. 3, fig. 76, the head of this rivet is of conical form, and it is intended to fill a rivet hole which has been countersunk. In laying up the rivet head, though the hole should be completely filled, the rivet head must project at least $\frac{3}{16}$ths or $\frac{1}{4}$th of an inch beyond the plate.

When this rivet has failed, it has generally been brought about by allowing too little projection, with the result that when heavy stresses have been experienced, the rivet head has not possessed sufficient holding power, and it has been torn through the rivet hole. However, where care is exercised, and rivets with insufficient head projection are condemned and renewed, excellent results are obtained. It is evident that this rivet is more successful where the thicknesses of the plates or bars which it connects are considerable, as it depends for its holding power very largely upon the depth of the countersinking. Where the material connected is thin, the pan-head rivet is preferable. The point of the plug-head rivet may be formed similarly to the methods described for the point of the pan-head rivet. Pan-head rivets have been used in practically every part of iron and steel ships. The plug-head rivet has found special favour for the inner bottom plating of double-bottom tanks, certain parts of the shell plating, oil- and water-tight bulkheads.

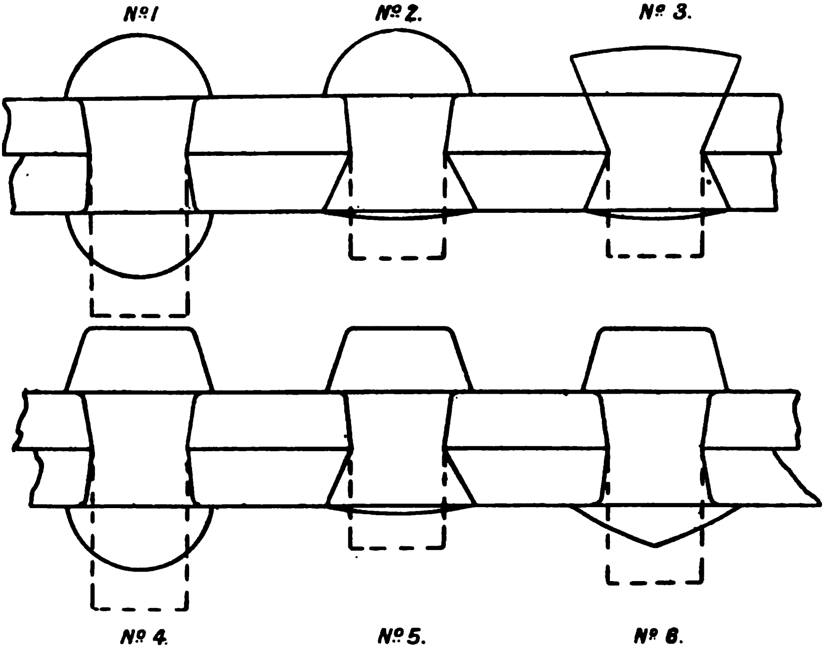
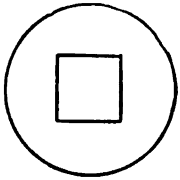
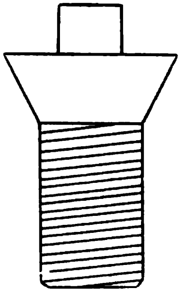


FIG. 76.—Forms of Rivets.

Snap-head Rivets.—Another form of rivet used is that known as the snap-head rivet (see Nos. 1 and 2, fig. 76). As the semi-spherical head is very neat in appearance, this rivet is usually adopted in such internal parts of the vessel as are exposed to view, and where it is desired to give a finished appearance, such as in engine-room bulkheads, engine and boiler casings, etc. It is preferable that the rivet neck be swelled as shown in Nos. 1 and 2, fig. 76, thus better filling the hole. The point of the rivet may be either beaten down, or finished off flush with the rivet hole well countersunk. Sometimes, however, to form the point like the head is desired. This is done by placing a snap cup over the heated rivet point, after it has been put into place, and hammering the same until the head is clenched, and the semi-spherical form obtained. When this work can be performed by machinery (hydraulic, etc.), satisfactory results are obtained. But where the riveting is done by hand, the results are not always efficient, the tendency being, in hammering the snap cup over the rivet point, to press the edges of the rivet close, and to leave a hollow all round under the newly-formed head. At first detection is not easy, as the riveting appears to be quite tight, but should water eventually find its way under the newly-formed rivet head, corrosion takes place round the edge of the rivet and in the plate upon which it bears, and the result is that in the course of time the rivet becomes loose. Owing to the uniform and enormous pressure obtained in machine riveting, the objectionable tendency just referred to does not exist. In any case, snap riveting is greatly inferior to that previously described for pan and plug-head rivets. As is apparent, it is much more difficult to lay up a snap rivet head, especially if performed by hand.



Plan of Rivet Head.



Tap Rivet.

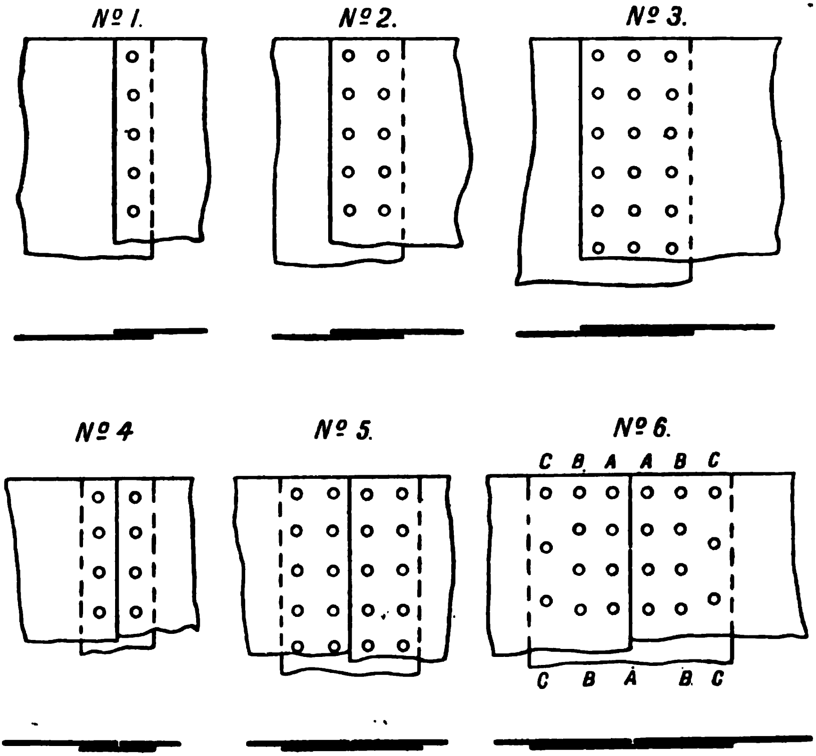
FIG. 77.

By laying up a rivet head is meant the operation of holding on to the rivet head by means of a heavy hammer, while the point is being beaten up and finished off, during which time the holder-on works his heavy hammer round the rivet head, thus thoroughly bringing it into close contact with the plate or bar.

Tap Rivets.—Another form of rivet used in ship work is the tap rivet. Its form is shown in fig. 77. It will be seen that it has a conical head with a thread turned upon the length of the rivet below. Upon the top of the head there is a rectangular projection. This rivet is used in places where it is difficult to get to the back of the material being riveted, in order to hold on, and finish off the point; or where it is desired to connect a comparatively thin plate to a thick bar or forging (stern frame, stem, etc.). The outer plate is countersunk to receive the rivet head, while a thread is put upon the lower portion of the rivet hole. The rivet is screwed into this by means of a key, and when thoroughly closed up, the projection on the head is chipped off.

Butt Straps, Butt Laps, etc.—The connection between two plates end to end is made either by fitting single or double butt straps, or by overlapping the plates.

Fig. 78 illustrates single, double, and treble riveted butt lap and butt strap connections.



Single Riveted Butt Lap.

Double Riveted Butt Lap.

Treble Riveted Butt Lap.

Single Riveted Butt Strap.

Double Riveted Butt Strap.

Treble Riveted Butt Strap.

FIG. 78.

Comparison of Butt Lap and Butt Strap Connection.—Rows or strakes of plating such as are found in the shell, decks, etc., are usually connected at their edges by overlapping the plates, excepting in the case of yachts, where, for the sake of appearance, a flush, smooth surface is preferred. In all cases, however, the overlap connection, when there are sufficient rivets properly spaced, is more efficient than the single strap connection. An attempt has been made to illustrate this in fig. 79, A and B. In B is shown a double riveted single butt strap; in A, a double riveted overlapped butt. Suppose, in each of these cases, a tensile stress is experienced. The direction of the line of stress will be that shown by the dotted line which passes in the direction of the strake of plating between the butts, and at the butts necessarily through the butt strap, which is the binding agent. In any case when such a stress is borne, the tendency is that it should be exerted in a straight line, which means that the tendency is to bring the butt strap into the same plane as the strake of plating. This necessarily produces an amount of pressure varying with the degree of stress at the back of the butt, which, though thoroughly well caulked before these stresses are experienced, tends to press forward the plating at the butt, and open the butt (as illustrated in an exaggerated form, see D, fig. 79), and produce leakage. Such results have actually taken place in many vessels, especially in the shell plating at the bilge, and it has not infrequently happened that the only way in which this damage could be effectively repaired has been by fitting an extra butt strap on the outside. In this case, the stress divides itself between the two butt straps, producing a pressure upon each side of the butt which neutralizes itself and renders impossible any further working at the butt. This also explains why, in many of the important structural parts of very large vessels (sheer strake, bilge plating, upper deck stringer plate, etc.), double straps are fitted. The advantage of an overlapped butt over a single-strapped butt will be apparent on examining the butts in fig. 79. Here (A and C), though an equal amount of stress may have to be borne, no tendency to open or destroy the efficiency of the caulking

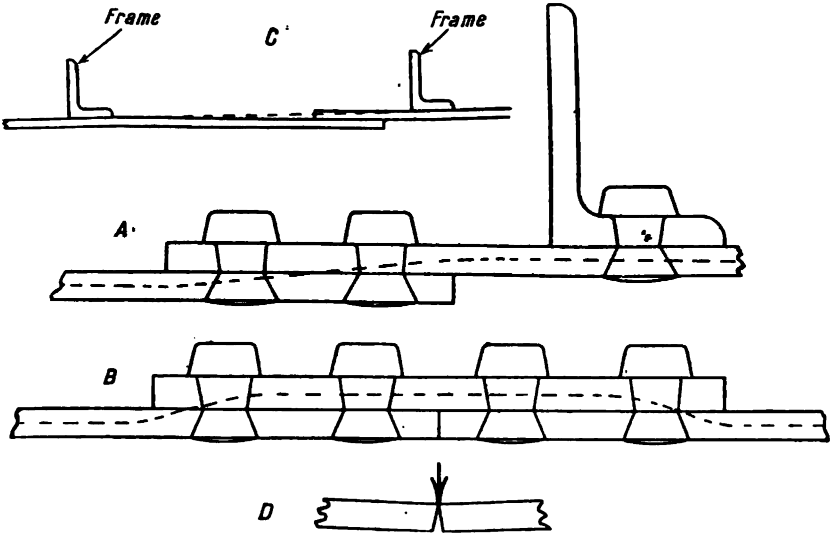


FIG. 79.—Butt Lap and Butt Strap Connections.

exists. It may be noted that, under both tension and compression, the stress is borne by the rivets in the overlap butt, while, in the case of the strapped butt, the ends of the plates at the butt bear hard upon each other under compression, the rivets being only subject to stress under tension.

Strength of Butt Connections.—To observe a few of the considerations which must be kept in view in arranging the rivets in butt connections will be advisable at this point. Let fig. 80 represent part of the shell plating of an ordinary mercantile steamer whose butts are connected by means of single straps in the three upper strakes, and, for the sake of example, by butt laps in the three lower strakes of plating. In way of every frame, the shell plating must necessarily be perforated with a line of rivet holes round the whole girth from gunwale to gunwale, spaced according to the usual practice, 7 to 8 diameters of the rivet apart. Especially is it essential that no butts in adjacent strakes of the outside shell plating should come nearer to each other than at least two frame spaces, nor in alternate strakes than one frame space. This rule has therefore been observed in fig. 80.

Now, assuming that a severe shearing stress is experienced, and that the strakes of plating are composed of continuous material without any butts, it follows that rupture could only take place through one of the lines of frame rivet holes, say, through S S. But supposing the butt connection at Y Y to be exceedingly weak, the rupture would then most likely occur by shearing the plate through S X, and shearing all the rivets on one side of the butt strap, and so on down the line of the nearest frame rivets as shown. From this, it will be seen that to attempt to make the butt connection as strong as the unpunched plate would be absurd, for, if such were possible—which obviously is not—in the application of continuously increasing stress as we have shown, the plating would ultimately shear through one of the lines of frame rivet holes. The efficiency, therefore, of the butt connection depends upon its strength relatively to the strength through a line of frame rivet holes in the strake of plating in which it comes.

The minimum shearing strength necessary for the rivets on the one side of the butt Y Y should equal the strength of the plate through the line of nearest frame rivet holes, say, P P. Had the frame spacing been wider, or the butt straps only double riveted, there would have been one or more pairs of rivets in the seams between the frame and the edge of the butt strap. (See, for example, butt laps, fig. 80.) In such a case, before rupture could occur at the butt, not only would the rivets on one side of the butt have to be sheared, but these additional seam rivets also between the frame and the butt strap. The shearing strength of all the rivets on one side of the butt plus the additional seam rivets just referred to, should equal the shearing strength of the plate through the line of the nearest frame rivet holes, or, in other words, the minimum shearing strength of the rivets on one side of the butt strap should equal the strength of the plate through the line of nearest frame rivet holes less the shearing strength of the additional seam rivets. Having arrived at the minimum number of rivets required for each side of the butt, they must now be disposed in such a manner as to produce no unduly weakened section in either the plate or the butt strap. A row of closely-spaced rivet holes, however, cannot be avoided on each side of the butt, A A, in fig. 80, this being necessary in order to ensure watertightness. The usual disposition of the rivets in treble riveted butt straps is shown in the three upper strakes in fig. 80, and also in fig. 78, No. 6.

There are five different ways in which fracture may occur at such connections. (See figs. 80 and 78, No. 6.)

(1) By the butt strap shearing through A A.

(2) By the plate shearing through C C.

(3) By the plate shearing through B B, and shearing the rivets in the row farthest from the butt, viz., C C.

(4) By the butt strap shearing through B B, and shearing all the rivets in the line A A.

(5) By all the rivets shearing on one side of the butt strap.

Were the row of rivets farthest from the butt spaced as they are in the other two rows, another particularly weak section would be created, for, as we have already stated, by the plate shearing through C C, total separation would occur. These rivets, however, are always more widely spaced. For moderately small vessels, Lloyd's require that every alternate rivet be omitted in the back row. For large vessels, however, a somewhat closer spacing is required, usually about 5 to 5¼ diameters of the rivet from centre to centre. Were the butt strap of the same thickness as the plating, it is clear that by far the weakest section would be through the line A A, fracture of the butt strap through this line producing total severance of the plate However, the necessary strength can be provided, as is usual, by increasing the thickness of the strap, and as a result the sectional area of the material through this line.

The tensile strength of the butt strap through the line of rivet holes A A should equal the strength of the plate through the line of rivet holes C C. The strength of a butt-strapped connection cannot exceed that of the plate through the line of rivet holes farthest from the butt.

Thus, classification societies demand one or several twentieths of an inch more thickness in the butt straps than in the plates they connect, over the vessel's midship length. For a similar reason, double butt straps should be each more than half the thickness of the plates they connect, while at the same time almost double the shearing strength is obtained in the rivets. When overlapped butts are adopted (see three lower strakes in fig. 80), the minimum shearing strength of the rivets is determined as previously described for the rivets on one side of the butt strap. As the rivets must be closely spaced in the row nearest to the caulking edge of the butt, no advantage whatever is gained by increasing the spacing of the rivets in the row farthest from the caulking edge, whether be double or treble riveted, as the strength of an overlapped bu cannot exceed the strength of the plates through the line of riv nearest to the caulking edge of the butt. In a deck stringer pl strength of the plate in way of a line of beam rivet holes regula minimum shearing strength of the rivets in a butt joint.

Classification Societies' Rules for Riveting.—While it is natura every student of naval architecture should desire to possess an inte reason for the methods adopted in practice in ship construction, it n pointed out that the registration societies give very full and con information, not only as regards the scantlings of vessels classed with but also as regards the size, spacing, and number of rivets to be us the various connections. And even in the case of vessels which ar classed with any registration society, the practice of the societies, at rate in regard to riveting, is, as a rule, very closely followed. Indeed, is a natural consequence, as Lloyd's Rules for the year 1885 are the stan upon which all British vessels are judged in being assigned a load line.

For the sake of illustration, we will notice some of the princ requirements of Lloyd's society.

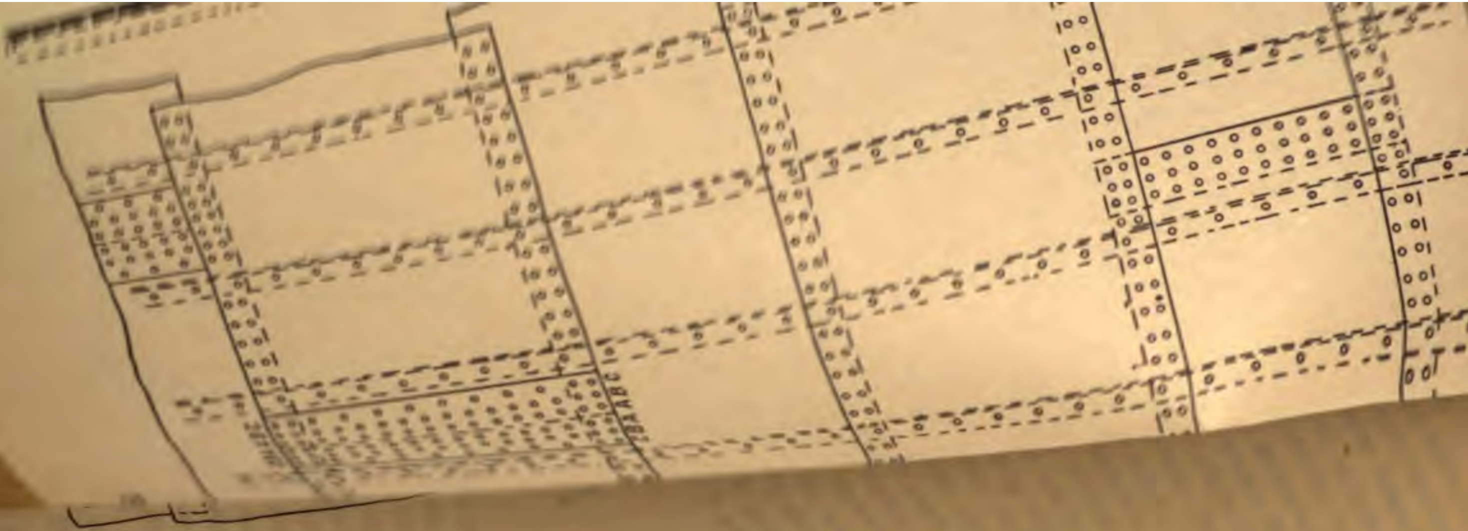
A rule that should be observed in all rivet work is, that no rivet sho come nearer to the edge of any plate or bar than its own diameter. connecting two plates or two angle bars, or a plate and an angle bar any important structural part, the greater thickness regulates the diamet of the rivet to be used. The corresponding diameters of rivets for plat or angles increasing in thickness is given in the adjoining table.

TABLE OF RIVETING.

Thickness of Plate in $\frac{1}{20}$ths of an inch.	5, 6	6 & 7	7, 8, 9	9 & 10	10, 11, 12, 13	13 & 14	14, 15, 16, 17	17 & 18	18, 19, 20
Diameter of Rivets in inches.	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{7}{8}$	1	1	$1\frac{1}{8}$	$1\frac{1}{8}$

When the outside shell plating is $\frac{7}{20}$ths of an inch in thickness and above from the keel to the upper turn of the bilge, and $\frac{9}{20}$ths of an inch and above from the upper turn of the bilge to the sheer strake, the seams or landing edges of the strakes of plating are to be double riveted. The seam on the lower edge of the sheer strake must, in all cases, be double riveted; for less thicknesses, the edges may be single riveted. In double edge riveting, the space between the rows of rivets must be at least once and a half their diameter. The distance between the centres of the rivets in a fore and aft direction should not exceed 4 to $4\frac{1}{2}$ diameters.

When the butts of the shell plating are overlapped, the butt must be treble riveted with three complete rows of rivets for at least one-half of


ZBA ABC

the rivets in the row farthest from the caulking edge, whether the butt be double or treble riveted, as the strength of an overlapped butt joint cannot exceed the strength of the plates through the line of rivet holes nearest to the caulking edge of the butt. In a deck stringer plate, the strength of the plate in way of a line of beam rivet holes regulates the minimum shearing strength of the rivets in a butt joint.

Classification Societies' Rules for Riveting.—While it is natural that every student of naval architecture should desire to possess an intelligent reason for the methods adopted in practice in ship construction, it may be pointed out that the registration societies give very full and complete information, not only as regards the scantlings of vessels classed with them, but also as regards the size, spacing, and number of rivets to be used in the various connections. And even in the case of vessels which are not classed with any registration society, the practice of the societies, at any rate in regard to riveting, is, as a rule, very closely followed. Indeed, that is a natural consequence, as Lloyd's Rules for the year 1885 are the standard upon which all British vessels are judged in being assigned a load line.

For the sake of illustration, we will notice some of the principal requirements of Lloyd's society.

A rule that should be observed in all rivet work is, that no rivet should come nearer to the edge of any plate or bar than its own diameter. In connecting two plates or two angle bars, or a plate and an angle bar in any important structural part, the greater thickness regulates the diameter of the rivet to be used. The corresponding diameters of rivets for plates or angles increasing in thickness is given in the adjoining table.

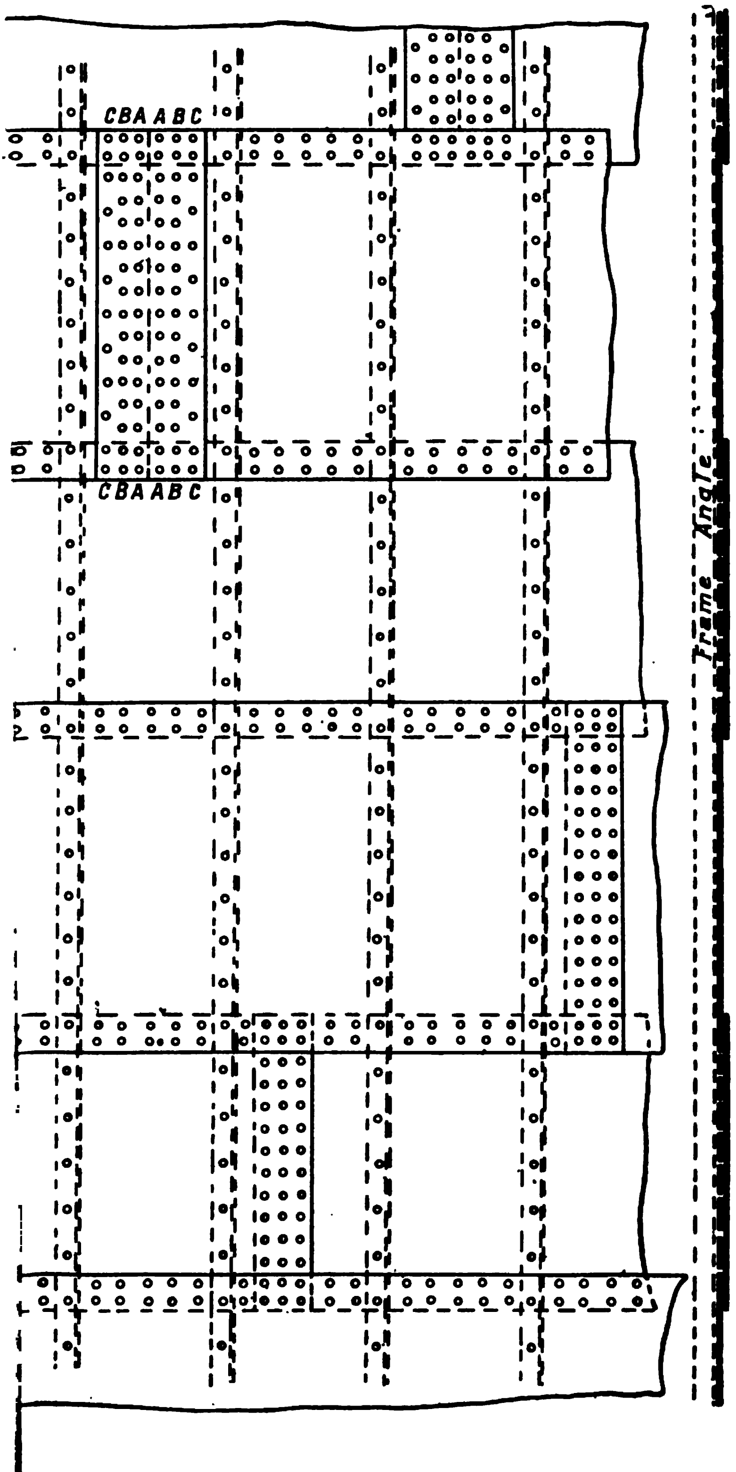
TABLE OF RIVETING.

Thickness of Plate in $\frac{1}{20}$ths of an inch.	5, 6	6 & 7	7, 8, 9	9 & 10	10, 11, 12, 13	13 & 14	14, 15, 16, 17	17 & 18	18, 19, 20
Diameter of Rivets in inches.	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{7}{8}$	1	1	$1\frac{1}{8}$	$1\frac{1}{8}$

When the outside shell plating is $\frac{7}{20}$ths of an inch in thickness and above from the keel to the upper turn of the bilge, and $\frac{9}{20}$ths of an inch and above from the upper turn of the bilge to the sheer strake, the seams or landing edges of the strakes of plating are to be double riveted. The seam on the lower edge of the sheer strake must, in all cases, be double riveted; for less thicknesses, the edges may be single riveted. In double edge riveting, the space between the rows of rivets must be at least once and a half their diameter. The distance between the centres of the rivets in a fore and aft direction should not exceed 4 to $4\frac{1}{2}$ diameters.

When the butts of the shell plating are overlapped, the butt must be treble riveted with three complete rows of rivets for at least one-half of the vessel's length amidships. When the second numeral or the plating

G.



number is less than 16,000, the overlapped butts at the ends may be double riveted; but when above 16,000, the lap butts are to be treble riveted throughout.

Between each row of rivets in butt straps there must be a space equal to twice, and in lapped butts twice and a half, the diameter of the rivet. In the other direction, the rivets in the butts must be not more than 3½ diameters apart from centre to centre.

When the shell butt connections are effected by means of butt straps, and the 2nd numeral is above 28,000, the whole of the butt straps all fore and aft are to be treble riveted. When above 24,000 and not exceeding 28,000, they are to be treble riveted for three-fourths the length amidships; and when above 20,000 and not exceeding 24,000, the butts are to be treble riveted for half the vessels length amidships. Below 20,000, treble riveting is only adopted in the butts for the more important strakes of shell plating, such as the sheer strake, and one or more bilge strakes. In very small vessels the butts need only be double riveted. The rivets through the shell plating which take the frames are spaced from 7 to 8 diameters apart, and in order that the frame may not be unduly weakened, when the seams are double riveted, by there being two rivets close together through the frames on every seam, one of these is omitted, the one left being the rivet nearest to the caulking edge. (See fig. 80.) Where, however, the seams are joggled, as in fig. 45, two rivets are preferable through the seams on the frame, so that the first rivet from the seam through the frame may be quite clear of the bend on the plate.


Bosom Piece.

FIG. 81.—Angle Bars.

The butts of deck stringer plates should be at least double riveted, whether they be strapped or overlapped. As vessels increase in size, it becomes necessary to treble rivet the butts, and even to fit double butt straps. The spacing of the rivets in the butts is similar to that previously given for shell butts. The butts of a steel deck are to be double riveted for half the vessel's length amidships, and the seams to be single riveted 4 to 4½ diameters apart. The rivets connecting a steel deck to the beams are spaced 7 to 8 diameters apart.

In inner bottom plating, the butts and edges of the middle line strake all fore and aft, and also the butts of the inner bottom plating in the engine and boiler space, should in all cases be double riveted. Elsewhere, where the 2nd numeral is 20,000 and under 30,000, the butts of the inner bottom plating should be double riveted for half the vessel's length amidships. In larger vessels it becomes necessary to double rivet both butts and seams for at least half the vessel's length. The butts of outside plating, deck plating, inner bottom plating, are chain riveted. In bar keels, stem bars, and stern frames, double zigzag riveting should be adopted in all vessels. Rivets through keelsons, bilge and side stringers, floors, frames, reverse frames, beams, are spaced about 7 diameters from centre to centre. The butt connections of angle bars are effected by fitting either a bosom piece, as shown in fig. 81, or a butt covering bar, as shown in fig. 9, where a heel piece or butt covering bar covers the frame butts on top of the bar keel.

Keel Blocks and Launching Ways.

Method is a most important factor in the successful management of a shipyard, where possibly several vessels of different sizes are in various stages of construction at the same time. Without a rigorously followed system, a state of chaos would undoubtedly supervene, and great loss would ensue, simply because of the time which would inevitably be wasted. Only those who have had actual shipyard experience know how true this is.

Though a shipyard be well equipped with first-class plant and machinery, and thoroughly capable workmen and officials, there is a large amount of very important and responsible work to be completed before a single frame of the ship can be hoisted into position on the blocks.

First of all, a suitable berth has to be chosen in which to build the proposed vessel. If the ground has a gentle natural declivity, all the better, as is soon discovered when the work of laying the keel blocks is about to be done. The ground must be firm, so that no sinkage or shifting of the earth takes place when the enormous weight of a large vessel is upon it. To ensure a good foundation, in some cases piles of timber are driven into the earth, and in other cases enormous blocks of timber, 12 in. or more square, are embedded in the earth, so that the uppermost surface is level with the ground. The baulks are laid in a fore and aft direction parallel to the keel line. Having secured a sure foundation, the blocks are arranged upon which the keel is to be laid. (See fig. 82.)

Everyone acquainted in any degree with ships understands that when a vessel is so far completed as to be ready for launching, what are called "launching ways" are laid under each side of the bottom between the bilge and keel. (See fig. 82.)

And naturally, as a vessel is generally launched by the impetus created by her own weight, the launching ways must be laid on such a declivity as will cause the vessel to move by her own weight when she is freed. The declivity given to launching ways is usually about $\frac{5}{8}$ in. to 1 ft., while the declivity of the keel blocks is made slightly less, say, $\frac{1}{2}$ in. to 1 ft. Consequently, where the ground has only a very slight natural slope, the stem of the vessel gets nearer and nearer to the earth every foot it travels in its journey down the launching ways. It is therefore of vital importance that a sufficient height be given to the foremost keel block, to

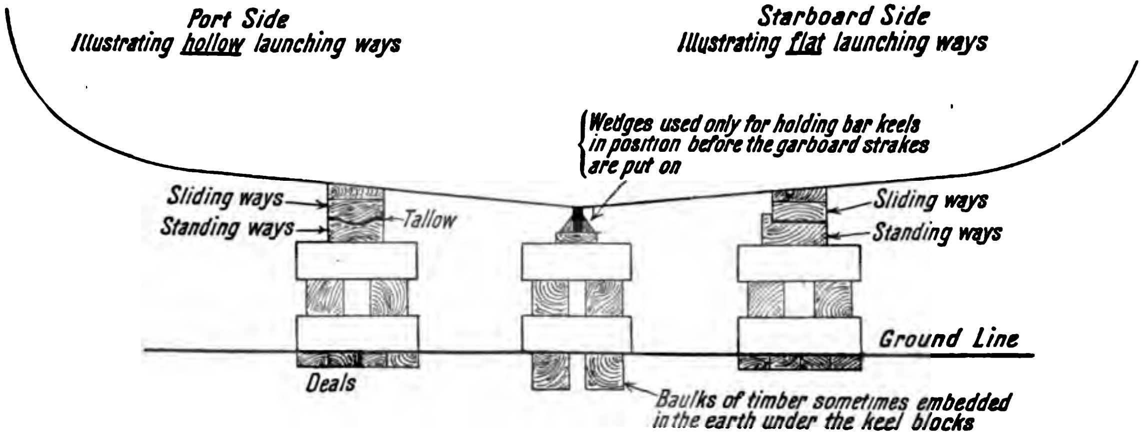


FIG. 82.—Keel Blocks and Launching Ways.

FIG. 83.—Declivity of Keel Blocks.

Notes.—1 ft. clearance for stem at water's edge.
4 ft. 1½ in. head room under keel at stern.

ensure that the stem will clear the ground just before she makes her final plunge into the water. Considerable damage is sometimes done by the stem striking the dock or riverside in the operation of launching, simply because sufficient care was not taken to allow for ample clearance. Suppose the distance from the water edge to the foremost block to be 300 ft., and it is intended to make the declivity of the launching ways $\frac{5}{8}$ths of an inch, with a clearance of, say, 1 ft. at the water edge (keel blocks $\frac{1}{2}$ in. per ft.), the height of the foremost keel block will be $(300 \times \frac{5}{8}'') + 12'' = 16$ ft. $7\frac{1}{2}$ in. above a horizontal base line passing through the surface of the ground at the water's edge.

But supposing the ground to have a natural declivity of $\frac{3}{8}$ths of an inch to 1 ft., then 16 ft. $7\frac{1}{2}$ in. less $300 \times \frac{3}{8}'' = 7$ ft. 3 in., the height of the foremost block above the ground line. (See fig. 83.)

Thus the declivity given to the keel blocks, and the height of the foremost block, must be determined in conjunction with the declivity of the launching ways.* See further remarks upon "Launching," p. 207.

Laying Off.—After the plans of a vessel have been prepared in the drawing office, the first man who takes her in hand is the loftsman. His domain is the mould loft, where, after being provided with the "lines" plan from the drawing office, or else carefully measured or calculated particulars taken by the draughtsman from the "lines" plan, he proceeds to reproduce the "lines" plan upon the loft floor to actual size.†

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* With a ground declivity of $\frac{3}{8}$ in. per ft., to lay the keel at a greater inclination than $\frac{1}{2}$ in. per ft. is quite unnecessary, for if such were done it would make a very high, and consequently a very expensive, line of keel blocks and staging.

If the keel blocks were laid at $\frac{1}{2}$ in. per ft., the height of the keel blocks would give ample head room for riveting all fore and aft.

The proper method of determining the slope of keel depends on two things:—

1st. Launching the ship at such an angle with the water that the buoyancy moment should exceed the tipping moment, viz., $B \times d$ should always slightly exceed $G \times D$. (See fig. 163.)

2nd. As the ground slope is usually less than the keel slope, the keel should always be sufficiently high at the after end to permit of good riveting.

$\frac{3}{8}$ in. is a very common yard slope. (See particulars *re* "Lusitania" and "Mauretania," page 64).
$\frac{1}{2}$ in. ,, ,, keel ,,
$\frac{5}{8}$ in. ,, ,, launching ,,

These are in no way imperative, but are the average of ordinary practice for ships of about 300 ft. in length.

Short boats (about 100 to 150 ft. in length) are often launched with way slopes of 1 in. to $1\frac{1}{4}$ in. to prevent them tipping off the ways.

Fine-lined ships, large yachts, and small war-ships often have $\frac{3}{4}$ to 1 in. way slope to prevent tipping, and, in addition, the ways are run further into the river than usual.

Very often the launching ways are above the bottom of the keel at the fore end. This is done so as to keep the fore cradle as shallow as possible.

In this case the foreshore or ground between the ways is dug out. This is a particularly common practice in north-east coast shipyards. See fig. 27 and pages 57 and 58.

† The "lines" plan, which is usually drawn to a scale of $\frac{1}{4}$ in. to 1 ft., consists of three principal plans:—

1. A profile showing the sheer, the form of the stem and stern, the decks and

In addition to these plans, the loftsman is furnished with numerous detail plans, such as the midship section, giving the scantlings of the material, and drawings of the stern frame and stem bar.

It is obvious, even assuming that the ship draughtsman has most carefully designed his "lines" plan in the drawing office, and endeavoured to secure perfect agreement between his "buttocks," "sections," and "waterplanes," that when the loftsman "lays off" the ship to full size upon the loft floor (in chalk lines upon a blackened floor), numerous discrepancies and unfairnesses may be discovered. The loftsman's work is to rectify any such irregularities, and to produce perfect harmony and fairness in all lines which make up the form of the hull.

When this is done, he proceeds to prepare the results of his labour for the workmen who are to manipulate the material for the various parts of the structure. His chief work is to prepare what is called a *scrieve board.* This consists of a rectangular area large enough to take a full-sized midship section of the vessel, made up of stout planks 9 in. or 11 in. wide, which are tightly clamped together. He then transfers from the mould loft floor to the scrieve board the midship section of the vessel (to outside of frame), and afterwards every frame between the stem bar and stern post. By means of carefully prepared supple pine battens, which he bends round each frame on the scrieve board fixed by means of long steel pins driven into the board alternately on each side of the batten, he cuts or scrieves every frame into the scrieve board with a sharp-edged tool called a scrieving knife.

He also scrieves in all decks, stringers, keelsons, and floors. The shell plating seams or edge laps are also shown on the scrieve board, but these are usually painted on in white.

When the scrieve board is completed, the planks composing it are unclamped, and carried to the shed or shop in the shipyard near to where the frames and reversed frames are bent and the floor plates prepared. Here the scrieve board is again put together, and secured as before.

But the loftsman does much more than this. From detail plans supplied to him by the drawing office, he draws the stem bar, stern frame, rudder frame, etc., to full size, and from these, full-sized wooden templates are made, and sent to the makers of these parts, whether they be forgings or castings.

In a similar manner, the loftsman is responsible for the making of templates for other special parts of the vessel, and lays off or expands

stringers, and the form of longitudinal vertical sections of the vessel at certain intervals from the fore and aft middle line. These sections are called "buttocks" in the after body, and "bow lines" in the fore body.

2. A body plan showing the transverse sectional form of the vessel at the outside of the frames, taken at intervals in her length from stem to stern. Upon this plan are marked all decks, stringers, keelsons, the floors, and the edges of the strakes of shell plating.

3. A plan showing the form of the rail lines, and horizontal sections of the vessel (termed waterplanes) from the keel upwards.

certain parts which need carefully dealing with in detail, such, for instance, as the stern plating round the counter, etc. A very important mould made by the loftsman is the beam mould. The standard "camber" or "round-up" for midship beams upon weather decks is ¼ in. for every foot in the length of the beam. Thus, for a beam 40 ft. long at amidships the camber at the centre would be 40 × ¼ in. = 10 in.

Let fig. 84 represent the curve of the midship beam. As we travel towards the stem and stern, the length of the beam gradually becomes less and less, until at, say, *x* feet from the stern it is only 30 ft. The camber is *not* 30 × ¼ in. = 7½ in., for, as is easily seen, this would be an entirely different curve from that at amidships. The curve of every beam on any particular deck is obtained from the beam mould by setting off half its length on each side of the middle of the mould. By this means a uniform curve is preserved from stem to stern.

Decks below the weather deck may either be perfectly horizontal or have the usual camber. Generally speaking, camber is given to all decks, though not necessarily of the regulation "round."

With the keel blocks laid, and the scrieve board prepared, the workmen are in a position to proceed with the manipulation of the steel and iron, and the erection of the vessel bit by bit upon the blocks. By the time this stage has been reached, quantities of steel plates and bars will have been received by the storekeeper, and stacked in the yard ready to be handed out as required.

Fig. 84.—Beam Camber Mould.

As the only practicable method is to build from the keel upwards, our attention will naturally be first called to the keel.

From a comparison of the structural features of the section and profile, figs. 7 and 11, with the section and profile, figs. 13 and 14, the former for a vessel about 242 ft. in length, and the latter 443 ft., it will be seen that large vessels, though possessing a greater amount of material in their structure, are remarkably similar—practically identical, indeed, with small vessels in the detail work of construction.

While the description and illustration of the details of the construction of the vessel illustrated in figs. 5, 6, 7, and 11 will, to a considerable extent, serve our purpose, we shall not confine ourselves to this particular vessel, but, when found advisable, turn to vessels of different size or type or design. This, we believe, will be the simplest and most comprehensive course to pursue.

KEELS.

The Bar Keel.—The dimensions of a bar keel for this vessel (fig. 5) would be about 9 in. × 2⅜ in., the 9 in. representing the depth and the

$2\frac{3}{8}$ in. the thickness. It is made of forged iron, and is ordered in separate lengths, varying from 20 to 50 ft. or more. These lengths are united so as to form a continuous bar extending from the stem bar to the stern post, to both of which it is connected. The connections of the various lengths are made by means of scarphs. The scarph connection of a bar keel to a stern frame is illustrated in fig. 85. The scarphs connecting the several lengths of keel bars to one another, and the stem bar and stern frame to the keel, are in all respects identical.

The usual length of the scarph is about nine times the thickness of the keel, viz., $21\frac{3}{8}$ in. The thin half length of each scarph is called the lip end. The extremities of the lip ends which check into the adjoining lengths are about $\frac{3}{8}$ths in. or $\frac{1}{2}$ in. thick. The faces of the scarphs are planed and fitted as closely as possible, otherwise it would be difficult to caulk the bottom edge of the scarph to produce watertightness, which is absolutely essential.

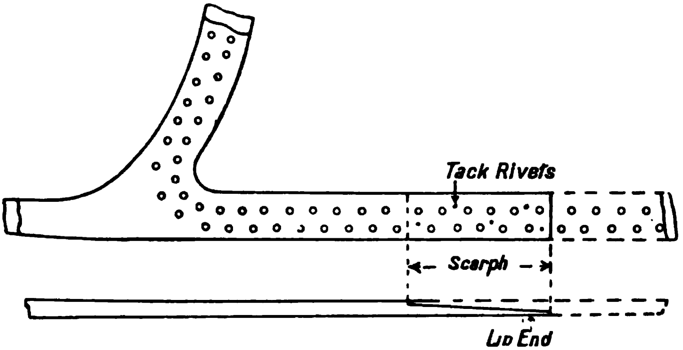


FIG. 85.—Stern Frame Connection to Solid Bar Keel.

Bar Keel Rivets.—The diameter of rivets used in the keel is $\frac{1}{4}$ in. more than the rivets required for plates of the thickness of the garboard strakes. The rivet holes are drilled $\frac{1}{16}$th of an inch larger than the diameter of the rivet. This is to allow for the expansion which takes place when rivets are heated, which provision is specially necessary when the diameter is considerable. The garboard strake for this vessel is $\frac{11}{20}$ths in. in thickness, and the table on page 116 shows that the diameter of the rivets required for this thickness is $\frac{7}{8}$ths in. The rivet therefore for the keel is $\frac{7}{8}$ in. + $\frac{1}{4}$ in. = $1\frac{1}{8}$ in. diameter, and the rivet hole is $1\frac{1}{8}$ in. + $\frac{1}{16}$ in. = $1\frac{3}{16}$ in. diameter.

The keel is always double riveted, that is, there are two rows of rivets. It is usual for these rivets to be arranged zigzag, as shown in fig. 85, though, on rare occasions, chain riveting has been adopted.

The rivets in each row are spaced 5 diameters apart from centre to centre. There should be about twice the diameter of a rivet between the edges of the rows of riveting. A most important rule in arranging the spacing of all rivets is, that no rivet should come nearer to the edge of a plate or bar than a distance at least equal to the diameter of the rivet. Now the garboard strake is never brought to the bottom of the keel, but is kept up about ¼ or ⅜ths of an inch. This is in order to permit of more satisfactorily caulking the bottom edge, and also to preserve the caulking in the event of the keel chafing over sandy bottoms or river bars. In some cases, it is found to be necessary to fit chafing plates or shoes over the bottom of the keel to preserve the lower edge of the garboard strake from wear from this cause. It also reduces the possibility of severe straining of the rivets, which might arise in the event of the vessel grounding upon the keel with a list, and one of the garboard strakes taking the weight of the vessel. The bottom rows of rivets must be kept *at least* one diameter of the rivet hole from the bottom edge of the garboard strake. At the same time, to keep the rivet too far from the edge of any plate which has to be caulked is a distinct objection, as it is difficult to satisfactorily close up the seam.

When the space between the rows is made more than two diameters of the rivet, it sometimes throws the top row of rivets so high that sound riveting is almost impossible. If the top rivets are upon the bend of the garboard strake, the work cannot be closed up, and on looking down between the floors, the rivet necks can be distinctly seen. Such work, needless to say, is most objectionable.

All rivet holes in the keel bars are drilled before the bars are fixed in place upon the blocks, excepting those in the lip ends of the scarph, which should be drilled after the keel has been fixed in position on the blocks, so as to avoid any blindness in the holes, which would be particularly objectionable in this locality. Before the frames are erected, and the garboard strakes are put on, the keel lengths are held in position by riveting them together by means of about half a dozen ⅞ths in. tack rivets through each scarph, spaced where found most convenient, and as far away from the other rivets as possible.

The scarphs are caulked before the garboard strakes go on, so as to ensure that no water finds its way into the vessel through the connections.

The bar keel is held in position on the blocks by means of chocks as shown in fig. 82, until the frames are erected and the garboard strakes can be put on.

Side Bar Keel.—In a vessel with a side bar keel, the centre through-plate (centre keelson) is continuous all fore and aft, and extends from the bottom of the keel to at least the height of the top of the floors (see figs. 6 and 121). The keel proper is usually made the same depth as required for a solid bar keel; and the total thickness of the centre girder and side slabs combined is equal to a solid bar keel. A most important condition which should be aimed at in the construction of side bar keels is, that the butts of the side bars and the centre through-plate, as well as the butts of the garboard strakes, be kept as far from each other as the lengths of the plates and bars will permit. For the reasons given, in dealing with bar keels, the garboard strakes should be kept at least ¼ in. from the bottom of the keel. The connection of the side bar keel to the stern frame is illustrated in fig. 86; and in an identical manner, the stem bar also is connected to the side bar keel. The riveting in all respects is similar to the riveting previously described for solid bar keels.

Flat Plate Keels.—A flat plate keel resembles an ordinary strake of outside shell plating, with the exception that it is of much greater thickness than the adjacent strakes (see figs. 7, 13, and 36). This is necessary, not only because of the wear and tear to which this plate is often subject, but because, in conjunction with the centre through-plate, which stands upon and is strongly attached to it, it is a considerable factor in the longitudinal strength. A flat plate keel is usually about 36 in. in width for ordinary vessels. The angle bars, by means of which the connection to the centre through-plate is made, are also of such size and thickness as is consistent with the thicknesses of the plates to be connected. The spacing of the rivets through the plate keel and these angles is about 5 diameters apart. The keel plate has the further assistance of the garboard strakes, which, though less than the keel plate thickness, are thicker than the adjacent plating.

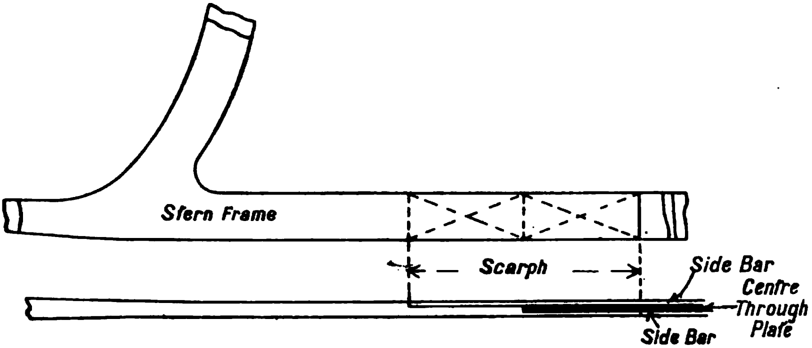


FIG. 86.—Stern Frame Connection to Side Bar Keel.

In some cases, a horizontal bar keel, or rubbing piece, as it is sometimes called, is attached to the centre of the keel plate by large rivets passing through both the keel plate and the horizontal flanges of the angles at the bottom of the centre through-plate (see fig. 13).

Frames, Reverse Frames, and Floors.

Frames.—The frames which, in figs. 1 and 5, extend continuously from the top of the keel to the gunwale, or to the poop, bridge, or forecastle deck stringer plate, are ordered in straight bars, and bent to the required shape in the shipyard by the frame benders. The rivets connecting the frame bar to the reverse bar and the frame bar to the shell, are spaced

7 to 8 diameters apart. All the rivet holes in the frame bar are punched before it is bent to its required shape, excepting those we shall now mention.

First.—The rivet holes on the turn of the bilge—which are apt to elongate and partially close up, owing to the amount of bending which takes place here.

Second.—The rivet holes in way of all the edge laps or landings of the strakes of outside shell plating—for as only one rivet is put through the frame in the way of shell landings (excepting in the case of joggled plating; see page 117) so as not to unduly weaken the frame, it is most essential that the hole be perfectly fair, in order to ensure the best workmanship. Although the positions of the laps are marked upon the frames before they are erected, it often happens, in checking the fairness of the fore and aft sight edge lines of these laps upon the ship herself, which is done by pinning a batten upon the frames after they are erected, a slight deviation has to be made from the marks upon the frames. Hence the necessity of omitting the punching of these holes, and drilling them at a later stage when all is fair.

Third.—The holes for beam knees are left unpunched also, with the exception of one hole, as, in fairing up the beam or sheer line, one or more beams might need slightly raising or lowering after being temporarily placed in position. The single hole punched in the knee is further necessary in order to attach the tackle for hoisting the beam up into place. The positions of the shell landings are obtained from the scrieve board by bending a light wooden strip round the particular frame being dealt with, and marking the laps upon it. On allowing the strip to spring straight again, it is laid upon the straight frame bar, and the position of the laps transferred. The space between the rivet hole in one lap and the rivet hole in the next lap is divided off into equal spaces representing, as nearly as possible, about 7 or 8 diameters of the rivet.

Punching.—It is of the greatest importance in punching, not only the frames, but all plates and bars throughout the vessel, that this be done from the faying surfaces.

The faying surfaces are those which have to bear against each other when riveted together, as, for instance, the faces of the frame and reverse angle flanges. The reason for this is, that in punching a plate or bar, the action of the punch is to leave a rag edge on the opposite side from that on which the punch enters the material. This would be a hindrance to any other plate or bar bearing close against it, which is absolutely essential to secure watertight, and, in all respects, satisfactory work. Moreover, the conical form of the punched rivet hole is better filled by the swelled neck of the rivet (see p. 110, Riveting).

Having punched the frame bar, the next step is to get it bent to shape. Generally, under the same shed in which the scrieve board is laid, there are what are known as the frame furnaces. In front of these furnaces there are laid large rectangular slabs of cast iron, 5 or 6 ft. square, and about 5 in. thick, which are perforated all over their surfaces with round or square holes about 1½ in. diameter. These iron blocks are so arranged as to form a perfectly horizontal surface of sufficient area to take the largest frame in the vessel.

In order to get the shape of the particular frame to be bent, a mould is made by means of a long strip of iron, called a set iron, which usually measures about 1½ in. wide by ½ in. or ⅜ths in. thick. When this has been bent to the shape of the toe of the frame on the scrieve board, it is taken to the cast iron blocks, and pinned down (see fig. 87).

However, not only have the frame bars to be bent to the shape of the section of the vessel, but they have to be bevelled also. Fig. 88 will illustrate this.

The frame angle has a long and short flange. The size of the frame angle for the vessel in figs. 1 and 5 is $4\frac{1}{2} \times 3 \times \frac{8}{20}$. The short flange *always* goes against the shell, and the long flange points towards the interior of the vessel, perpendicular to the fore and aft middle line. It will thus be seen that over part of the midship length of ordinary cargo vessels, where the form of the section is constant, the angle produced by the flanges of the frame bar is a perfectly right angle. Towards the ends of the vessel, however, where the hull tapers in to the stem and stern, the angle produced by the flanges of the frames must necessarily change. Did the shell flanges of all the frames point in the same direction, then at one end of the vessel the angles produced would become very obtuse, and at the other, very acute. But with an acute angle, or, as it is called, a closed bevel, to get good riveting is most difficult, and in some cases impossible, as the head of the rivet cannot be properly laid up. It thus becomes necessary, in order to get open frame bevels at the ends of the vessel, to reverse the frames at one end, that is, the shell flanges of the frame bars point towards amidships from both ends of the vessel. The reversing of the frame takes place at amidships (see fig. 88).

The bevelling of the frame bars can be done either by hand or by machinery. In small vessels, both the bevelling and the bending can be done in one heat, but for larger vessels two heats may be necessary. The amount of bevel to be given to the frames is supplied by the loftsman on a bevel board.

A possible danger in hand bevelling is that the shell flange may be made somewhat concave between the heel and the toe of the bar. This could only conduce to unsatisfactory riveting, hence it is necessary to carefully guard against it, and in some cases to chip off the projecting heel of the bar. In machine bevelling, the bar is bevelled from the heel, and this objection exists only to a very small extent.

To bend the frame, it is drawn out of the furnace after it has reached a full heat, and one end is pinned down to the end of the set iron, while the other is worked round to its shape, and pinned down and kept in position on the blocks by means of iron dogs and pins (see fig. 87). An important feature in the bending of angle bars is, that in the process of cooling, more contraction takes place at the heel of the bar where the material is thickest than anywhere else. The result is, that in a bar bent *from* the heel (as is the frame bar), the contraction causes the bar to somewhat straighten itself, producing a reduction in the curvature. Knowing this, the frame benders, guided by experience, give more curvature to the frame when it is in a heated state than the scrieve board indicates, with the effect that when the frame bar is cool, it has approximately come to the desired shape—so near, indeed, that a few blows from a hammer, when it is cold, bring it to the correct curvature. It is carefully tested on the scrieve board before any riveting is done. The corresponding frame bar for the other side of the vessel is made in a similar manner, and the two sides tested by laying one upon the other.

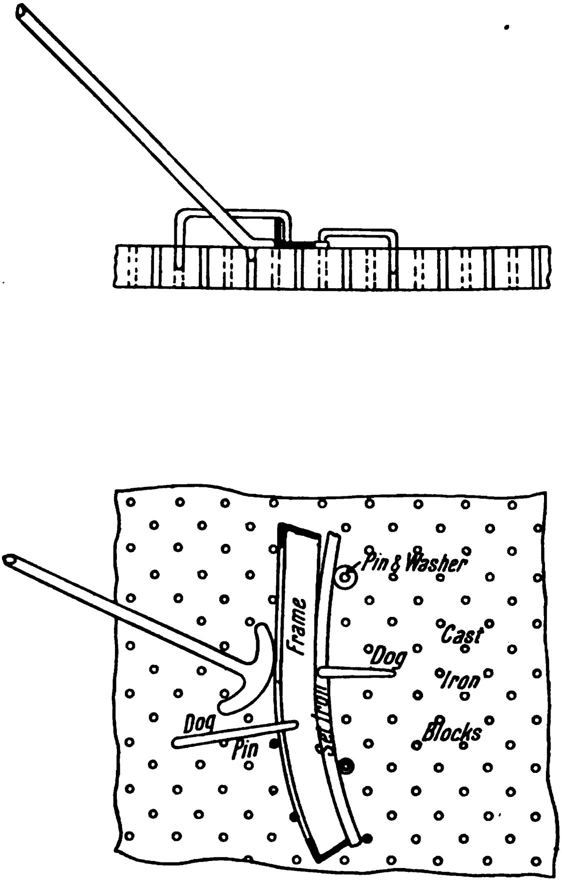


Fig. 87.—Frame Bending.

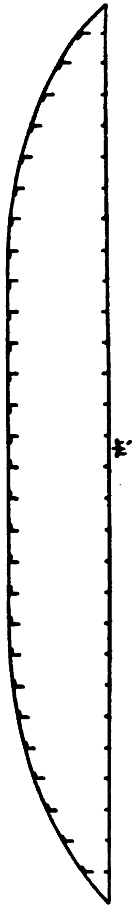


Fig. 88.—Showing Bevelling of Frames.

As the amount of external water pressure on the outside of a vessel is greatest where the immersed girth is greatest, and as it moreover naturally follows that greater weight is likely to be carried where the hold capacity is greatest, it is evident that more strength is required in the transverse framing in the full middle body of a vessel than towards the ends, where she gradually fines down into the stem and the stern. In order to provide this additional strength it is usual to increase the thickness of the frames $\frac{1}{20}$th in. over the three-fifths of the midship length. Similarly, the midship floors are always thicker than the floors towards the ends—a floor $\frac{9}{20}$ths in. thick amidships would probably be reduced to $\frac{7}{20}$ths at the ends.

Reverse Frames.—Like the frames, the reversed frame angles come into the shipyard in straight bars. They are considerably smaller than the frame angles, being, for the vessel in figs. 1 and 5, only $3 \times 3 \times \frac{7}{20}$. The holes for rivets connecting the reversed frames to the frames and floors, and those which take stringers and keelsons, are all punched after the bar is bent. The reversed frame is bent and bevelled in a manner very similar to that described for the frames. The set iron is made to the shape of the toe of the frame from its uppermost extremity down to the bilge, where it leaves the frame and takes the form of the upper edge of the floor plate.

Unlike the frame angle, the heel of the reverse frame comes against the set iron, and in cooling—most contraction taking place there—the tendency is for the bar to bend more than is given to it on the blocks. In this, again, the experience of the frame bender guides him in making due allowance, and when the bar has cooled, and is finally tested upon the scrieve board, a few blows from a hammer are generally sufficient to make any necessary correction. The holes in the unpunched flange taking the frame are transferred from the frame by laying the frame bar upon the reverse bar, and marking the rivet holes by means of a whitened wooden cylinder which is pushed through each rivet hole. The remainder of the holes connecting the reverse frame to the floors are spaced 7 to 8 diameters apart, and punched. Holes for keelsons and stringers are always omitted, and punched or drilled at a later stage. (For heights to which reversed frames extend in one, two, three deck, spar deck, and awning deck vessels, see Chapter III., pages 31 to 42, "Types of Vessels.")

In the engine and boiler space of steam vessels, double reversed frames should be fitted to every floor, and extend at least from bilge to bilge. In figs. 1 and 5 the reversed frames extend alternately to gunwale and to the top of the hold beam stringer angle; and in the way of the engine and boiler space, the double bars extend from upper bilge stringer to upper bilge stringer.

The spacing of the rivet holes in the flange connected to the frame angle will naturally be the same as the spacing in the frame (7 to 8 diameters of rivet) from which they were transferred. The rivets in the same flange taking the floors are spaced 7 to 8 diameters also. The rivet holes in the other flange taking the ceiling and sparring must be spaced to suit the width and arrangement of the battens.

Floors.—In the case of very small vessels, the floors are usually in one piece from bilge to bilge. But in larger vessels this is impracticable, and the plates forming the two parts of the floor are lapped, on one and the other side of the centre line alternately. The lap must be treble riveted (see fig. 6), or, if the butt be strapped, double straps treble riveted should be used.

As we have previously observed, the floors extend up the bilge in a fair curve to a height above the top of the keel of twice the depth of the floors at the middle line. But as it adds very materially to the cost of plates to have them cut hollow to shape by the manufacturer, the custom in all shipyards is to order all floor plates so that the top edge is a perfectly straight line. Indeed, only rarely are any plates ordered with a hollow in them, for the reason given. What the draughtsman does in ordering floor plates is to expand the floor with the top edge perfectly straight, and, in order to minimise waste, he orders the floor plate somewhat like the plate shown in fig. 89. The first operation, then, in dealing with the floor plate, after it has arrived on the shipbuilder's premises, is to curve its top edge to the shape of the particular floor on the scrieve board. Here, again, a set iron is bent to the required shape, and pinned on the iron bending slabs. The floor is put into the frame furnace and heated to a white heat. It is then brought out of the furnace, bent round the set iron, and pinned down with dogs. It is hammered when necessary, and care taken to prevent buckling. As the floor plate is inserted between the frame and reversed frame at the bilge — that is, just where the frames and the reversed frames diverge—the floor plate is heated again at the ends, and hammered out so as to produce a gradual wedge-shaped taper (see fig. 90).

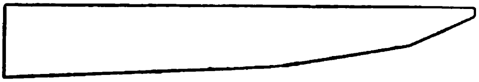


Fig. 89.—Floor Plate as ordered.

After the floor has cooled, the next step is to curve its outer edge to suit the frame. It is taken to the scrieve board, its upper edge is adjusted to its own floor curve, and the centre line over the keel is marked upon it. Its own frame, which is already bent, is then laid upon it, and the curve of its outer edge marked with chalk. At the same time, the rivet holes are transferred from the frame by the whitened wooden cylinder. In a similar way, by laying the reverse frame upon the floor, the rivet holes are transferred. The floor plate is then carried away and sheared—not, however, to the exact frame edge line, but about $\frac{1}{4}$ in. from the frame edge, so that when the floor attached to its frame is in position in the ship, there is no doubt about the frame flange bearing hard upon the shell (see fig. 90). According to the 1st numeral of this vessel (figs. 1 and 5), the depth of the floors on the keel should be $22\frac{1}{2}$ in., and at three-fourths of the half-breadth from the middle line the minimum rule depth $\frac{22\frac{1}{2}}{2} = 11\frac{1}{4}$, and the height from the base line—top of keel—to the top of the floor at the extremities should be $22\frac{1}{2} \times 2 = 45$ in.

Both the frame bars and the reversed frame bars for the two sides of the vessel butt at the middle line—the frames on the top of the keel, and the reversed frames immediately under the centre keelson. On account of the unavoidable interruption in the continuity of these parts of the transverse framing, butt straps must be fitted. Thus, covering the frame butt, we have a piece of angle bar 3 ft. long, of the frame size, riveted on the opposite side of the floors (figs. 1 and 4). This butt strap, or *heel piece*, as it is called, not only affords strength at the butt, but offers an additional means of securing a good connection to the garboard strakes, which in turn carry the bar keel. This is an important point, as the only connection which the bar keel has to the vessel itself is by means of the garboard strakes, to which it appears to hang. Hence the bar keel is sometimes termed a "hanging" keel. The reversed frame butt strap, or lug piece, is also fitted to the opposite side of the floor plate (figs. 1 and 4). Not only does it perform the function of a butt strap, but it also provides a double means of connection between the largest and the chief keelson in the vessel to the

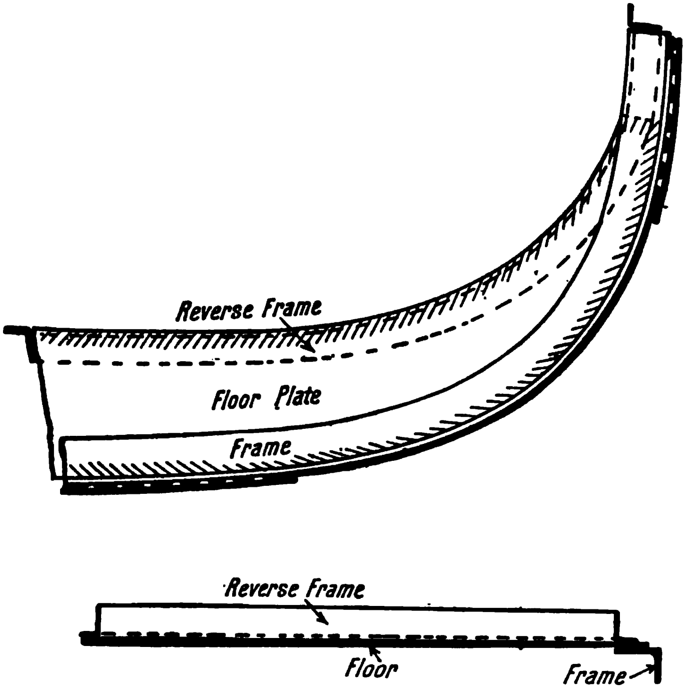


FIG. 90.—Showing Floor at Bilge.

transverse framing (see figs. 4 and 5). Indeed, wherever keelsons or stringers cross over the transverse frames, the connection should be made by means of these double reversed bars or lug pieces, even though no butt occurs in the ordinary reversed frame, and the lug should be long enough to take three rivets (see fig. 91).

Like the frames, and for the same reason, the floor plates are thicker over the three-fifths length amidships (from $\frac{1}{20}$th in. to $\frac{2}{20}$ths in.) than at the ends.

The special requirements of transverse framing in way of the engine and boiler spaces will be dealt with at a later stage under that heading.

Erection of Transverse Framing.—When the frames, reverses, floor-plates, and beams have been prepared, and their accuracy tested upon the scrieve board, they are carried to a staging at the stem of the vessel, and riveted together with or without the beams. They are then hoisted into their respective positions indicated upon the keel, and first of all (remembering the declivity of the blocks) given such a rake (angle of inclination) as will bring them perpendicular to the keel. This operation is termed "plumbing." The process of adjusting the frames, so that they cross the keel at perfect right angles, is called "horning." In a vessel with a double bottom, this expoditious system of erecting complete transverse frames cannot be carried out, the double bottom having to be erected first; usually in the order of keel, centre through-plate, floors, tank margin plate, and the frame legs hoisted into position after the framing of the double bottom has been practically completed.

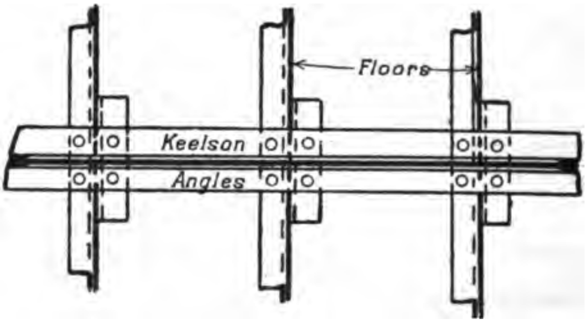


FIG. 91.—Showing Lugs upon Floors for Keelson Connection.

Double-bottom Framing.—The details of the transverse framing in vessels having double bottoms with continuous centre through-plates standing upon flat plate keels have already been fully described in Chapters II. and III. (see Water-ballast Arrangement). It might be noticed in passing, however, that where the floors are solid from centre through-plate to tank margin plate, the angle bar upon the lower edge of the floor plate by means of which the connection is made to the shell, need not have flanges larger than the smaller of the ordinary frame flanges. But where floors come upon alternate frames, as shown in fig. 71, with brackets only upon alternate frames, the frame angle in the tank should be of the full size. Both frame and reverse frame angles upon solid floor plates are sometimes dispensed with, the connection to shell and inner bottom being made by flanging the floor plates (see figs. 39 and 42 to 47).

Where side bar keels with continuous centre through-plates from bottom of keel to tank top are adopted, as shown in fig. 6, it is common for the frame angle in the tank to be continuous from margin plate to margin plate. In such case, a triangular hole must be notched out of the centre through-plate immediately above the keel, to allow the frame bar to pass through. In the erection of this form of double bottom upon the blocks, the centre through-plate and side bars are first fixed in position, followed by the tank frame bar, which is held up by means of shores; and after this, the floors with reverse bars and angles for the connection to the centre through-plate and tank margin plate are hoisted up and riveted to the frame.

Z *Frames.*—While the Z frame section of frames is preferable to the ordinary frame and reverse, its costliness, and the increased difficulty in bending and bevelling, have made its adoption comparatively rare in merchant shipbuilding, but in the Royal Navy it is extensively used. Figs. 39 and 42 to 47 are framed with Z bars. (All "turret" steamers are framed with Z bars).

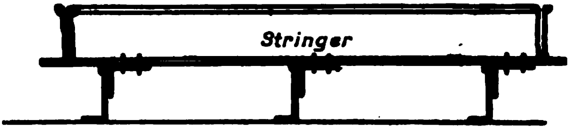


FIG. 92.—Bulb Angle Frames with large Lug for Stringer Connection.

Bulb Angle Frames (in lieu of frame and reverse).—Bulb angle frames (and also Z frames) are seldom adopted excepting in vessels with double bottoms; the shorter lengths of frames (frame legs) terminating, as they do, at the tank side, render the operation of bending and bevelling more easy of accomplishment. One noteworthy point about the bulb angle frames is that they have no fore and aft flange to which the stringers and sparring in the holds can be attached. This difficulty, however, is got over in the case of the stringers by fitting to that side of the transverse flange away from the bulb, a lug with a flange large enough to take double rivets (see fig. 92). The sparring is fixed by means of cleats. This type of framing is especially favourable in colliers—vastly less damage being done to the bulb by the bumping of coal than to the reverse bar in the ordinary system of framing.

Channel Bar Frames.—This excellent section, combining both frame and reverse bar, is commonly adopted, especially in large vessels with a long uniform midship body in which the channel frames require no bevelling. See page 53 *re* "Lusitania" and "Mauretania."

The difficulty of both bending and bevelling channel bars for frames, and the still greater difficulty of performing satisfactory riveting where much bevelling takes place, is sufficient reason for dispensing with them at the ends of vessels. Though channel frames may be used in vessels with ordinary floors, yet, like Z frames, they are usually adopted for the frame legs only in vessels with double bottoms. In some cases, extra deep channel frames have been used as compensation for an omitted tier of hold beams.

Deep Framing.—While the two large angles which go to make up what are termed deep frames take the place of the ordinary frame and reversed frame, their chief function, as has been pointed out in Chapter II., is to compensate for a tier of hold beams which are dispensed with. Instead of fitting together the two angles in the same fashion as is usual for the ordinary frame and reverse—the toe of the frame being flush with the heel of the reverse frame—the connection is made by means of a 3 or 3½ in. lap only, in which case it is preferable to fit the angles together as shown in the detail section in fig. 7. The lug piece which is usually fitted in order to get a good connection between the stringers and the transverse frames, is placed on the back of the reversed frame (see fig. 7). This is better than fitting the frame and reverse as shown in fig. 93, where not only is a piece of packing iron required, but satisfactory riveting is with difficulty obtained. Figs. 7 and 13 are framed on the deep frame system. It will be understood that deep framing compensating for hold beams may also be formed of Z bars, bulb angles, and channel bars, of suitable scantling.

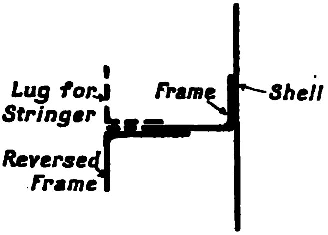


FIG. 93. — Inadvisable method of fitting the Reversed Frame in Deep Framing.

Like channel frames, deep framing is only adopted for the frame legs in vessels with double bottoms. The bending and bevelling is done as described for ordinary frames.

Web Frames.—See also Chapter II.

The width and spacing of web frames in lieu of a tier of hold beams is governed by the depth of the vessel, while the thickness of the plates is usually similar to that of the ordinary frames. In conjunction with web frames, web stringers of the same width as the web frames are fitted intercostally between the web frames. The number of these also depends upon the depth of the vessel.

A web frame is made up of one or more plates connected by treble riveted laps or straps. The connection to the shell is made by an angle of the frame size, and on the inner edge, by two angles of about the reversed frame size or one equivalent angle.

A section through the web stringers is shown upon fig. 6. It will be noticed that they are connected to the shell by an intercostal angle between the frames, and to the reverse frames by an angle which is intercostal between the web frames. On the inner edge of the web stringer plate are two small angles which may be substituted by a single angle as for web frames. The connection of the web stringer to the web frames is made by double angles, and also by diamond plates (see midship section, fig. 13). The connection of the web frames to the tank side is made by double angles also.

In order to make the transverse strength afforded by web frames as continuous as possible right round the transverse circumference of the hull, extra strong through beams with deep knees are fitted to the head of the web frames where practicable.

Figs. 6, 49, and 50 are midship sections of vessels built upon the web frame system. The sectional profile in fig. 48 will afford a good idea of the general arrangement of web frames and stringers.

Beams.

As a general rule, it may be stated that under iron or steel decks it is preferable to fit beams to *every* frame; that is, when the frame spacing is somewhat similar to what would be required according to Lloyd's Rules. They may consist, in small vessels, of plain angles, and in larger vessels of bulb angles or channel bars. The reason for this is, that if, with an average frame spacing of, say, 24 in. in a vessel 250 ft. in length, the beams were placed upon the alternate frames (4 ft. apart), the comparatively thin iron or steel deck, which structurally would be sufficient for such a vessel, would possess the tendency to fall hollow between the beams, which is most objectionable and unsightly. To place beams upon alternate frames under steel decks should only be attempted in very large vessels with thick deck plating. Indeed, Lloyd's Rules distinctly state that while it is preferable that beams be fitted to every frame under steel decks, it is only when the steel deck exceeds $\frac{7}{20}$ths of an inch in thickness that beams on alternate frames are permitted in their classification.

The steel upper deck of the vessel shown in fig. 7 is $\frac{6}{20}$ths in. in thickness, and the beams under it are placed upon every frame (24 in. apart). In figs. 13 and 14 the uppermost or shelter deck is only $\frac{6}{20}$ths in. in thickness, and the beams under it are again upon every frame; but the upper and main decks, which are of steel $\frac{9}{20}$ths and $\frac{8}{20}$ths in. in thickness respectively, have their respective beams on every alternate frame. Where a system of widely spaced frames is adopted, as has been pointed out in figs. 53 and 54, in which the spacing is 36 in., the beams under steel decks must of necessity come upon every frame.

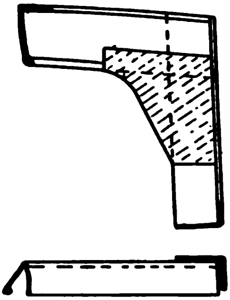
As the tendency to fall hollow between the beams in vessels with wood decks only practically does not exist, it is usual to fit beams of stronger section on alternate frames. They may consist of large bulb angles, tee bars, bulb tee bars or butterly bulbs, bulb plates with double angles on top, or channel bars, varying in dimensions according to the greatest breadth of the vessel.

Like the frame and reversed frame angles, the beams come into the shipyard in straight bars. But, as we have seen, all beams on weather decks, at any rate, should have a "camber" or "round up" of ¼ in. to every foot of midship breadth of deck. This result is obtained by cold bending in a "squeezing machine."

The length of every beam in the ship's deck is obtained from the mould upon which they are indicated. Having cambered the beams, and cut them to their respective lengths, the next step is to prepare the knees.

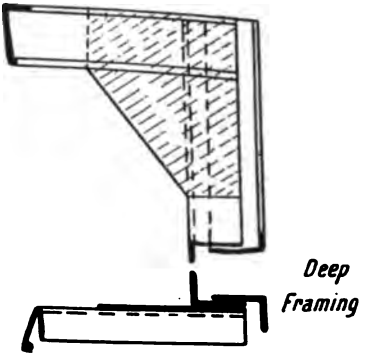
The depth of beam knees should be at least two and a half times the depth of the beam. The knees may be either welded or bracketed.

The welded knees are generally made by cutting off part of the bulb, and welding to its extremities a piece of plate of the thickness of the beams (see fig. 94, where the welded plate is shown by hatched lines). When the welding is well done, a stronger knee is formed by carrying the bulb round the edge of the knee.



Plan showing the Beam fitted into the Bosom of the Frame.

FIG. 94.—Bulb Angle Beam with Welded Knee.



Plan.

FIG. 95.—Bulb Angle Beam with Bracket Knee.

Bracket knees, as shown by hatched lines in fig. 95, consist simply of bracket plates riveted to the back of the vertical flange of the beam. In both these cases, the knees fit into the bosom of the frames (see plan in sketches). Beam knees of this size (14 in. in depth) should have *at least* four ¾-in. rivets connecting them to the frames, but not more than two rivet holes should be punched in any beam knee, or in the frame before the beam has been hoisted into place and adjusted.

Knees for plain angle beams, such as would be used for upper decks in smaller vessels, and for the poop and bridge of the vessel illustrated in figs. 7 and 11, are made in exactly the same manner as described for bulb angles.

Having prepared the knees, the spacing of the rivet holes in the horizontal flange of the beam taking the deck is the next operation. This is a more important work than one would at first imagine, and requires very considerable care. The general rule is, that rivets connecting an iron or steel deck are spaced from 7 to 8 diameters apart, but, as we shall show, the regularity of any such spacing may be greatly interfered with. Reference to the deck plan of the vessel in fig. 129 will help to make this clear. On the deck stringer plate, and round all deck houses, hatches, casings, etc., there are angle bars forming the connecting means between the deck and the sheer strake, or deck houses, or hatch coamings, etc., as the case may be. The positions of all such bars as these are supplied to the outside workman by the ship's draughtsman, either on a deck plan, or on what is called a beam list. Then, again, care has to be taken to set off all the rivet holes in the edge laps of the strakes of deck plating. After precautions have been taken to carefully mark off the positions of these particular rivet holes, the remaining rivet holes are spaced, as nearly as possible, 7 or 8 diameters apart. The holes are then punched.

The midship section, fig. 13, shows a section of the deck through a hatchway, and will further illustrate the points just mentioned. See also fig. 101 (channel beam).

When a wood deck is laid upon the beams, then, in addition to marking off the positions of deck angle bars, tie plates, etc., the holes in the deck flange or flanges of the beam through which the wood deck bolts pass, must be arranged to suit the width of the deck planking. Wherever beams are fitted to every frame or alternate frames, they must be tied together so as to preserve the proper spacing between them, and thus keep them in their correct positions relatively to one another. When a steel or iron deck is laid upon the beams, the deck itself admirably performs this function, but when only a wood deck is laid upon the beams, continuous iron or steel tie plates, laid in a fore and aft direction across the beams, assisted when necessary by diagonal tie plates, are required. These tie plates vary in width from 6 in. to 30 in. or more, and, in addition to serving the useful purpose just mentioned, act like a steel deck in distributing stresses thrust upon the deck in any locality (from masts, etc.) from beam to beam, and to the stringer plates.

Plates somewhat similar to these tie plates should be fitted to the beams along the sides and round the ends of the hatchways, engine and boiler openings, companion ways, and all other deck openings, so as to get a better connection for the angle bars which go round the coamings of all these openings.

In the way of all hatchways, the beams necessarily only extend from the frame to the hatch coaming. When the hatchways are very long, and when they come in the middle length of the vessel, the result must be a very serious reduction in transverse strength, unless adequate measures are adopted to compensate for the interruption in the continuity of these transverse girders. In any case, it is necessary to carefully protect all deck openings, especially when situated upon the weather deck—these being most exposed to the attacks of shipped seas, etc. This protection is afforded to hatchways by fitting vertical side plates, or *hatch coamings*, along the sides and ends of the openings, and carrying them to a height of at least 2 ft. 6 in. from the deck. These hatch coamings not only afford protection to the hatch openings, but also a means of binding together the beam ends, and provide the compensation previously referred to.

First of all, we notice in the profile, fig. 11, that at all hatch ends an extra strong deep beam is fitted, consisting of a bulb plate and an angle (or it may be a strong channel bar or some equivalent), instead of the ordinary bulb angle beam. At the hatch ends, the coaming plate is carried down over this beam to the top of the bulb, and securely riveted to it with a double row of rivets as shown in the section of the beam, fig. 96.

Instead of the side or fore and aft hatch coaming plates extending from the deck only to their prescribed height, they are carried down well over the ends of all the half beams, or flanged round the bottom of the beams, as shown in figs. 13, 60, and 101. When the hatch corners are round, which is the more preferable method of construction in every respect (except for cheapness), the coamings are continuous all round the hatchway, the separate plates composing the whole coaming being connected by double riveted butt straps. These hatch coamings should be made of good stout plates, $\frac{8}{20}$ths in. or $\frac{10}{20}$ths in. thick, in vessels of average size. It will now be seen what an excellently strong and suitable arrangement the hatch coamings become, upon which to hang, as it were, the ends of the beams which are necessarily cut in way of all hatches. By the hatch end coaming plates being well riveted to the strong hatch end beams, the side coaming plates become exceedingly strong fore and aft girders well able to carry the beams and the deck at the hatch side, that is, of course, in conjunction with the assistance afforded by the hold stanchions, which are fitted along each side of all large hatchways (unless special compensation is introduced for dispensing with them; see "Steam Collier," page 87), and well connected to the beams. Indeed, the hatch coamings are formed into a strong, rigid

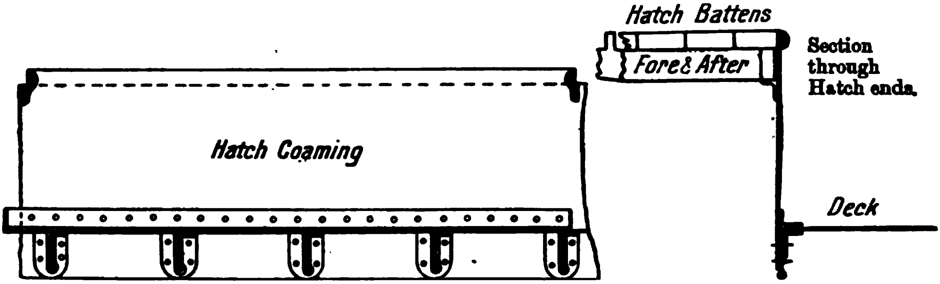


FIG. 96.—Side Elevation of Hatch Coaming Plate, showing angle connection to deck plating and collars on beam ends.

girder framework, well connected to the main structure of the ship at the hatch ends. It is when labouring at sea that the section of the vessel in way of the hatches is liable to develop weakness, but, as shown in the further reference to hatchways (p. 194), transverse stiffness is afforded by the introduction of portable transverse web plates between the coamings (see figs. 11 and 101).

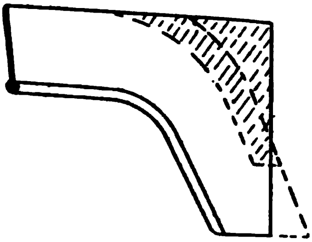
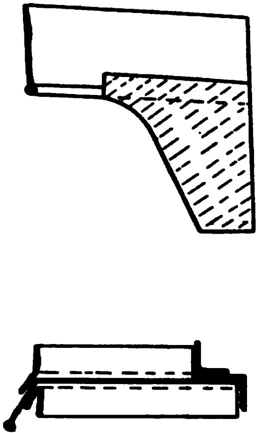


FIG. 97.—Bulb Plate Turned Knee.

When the hatch coamings have square corners, the side and end plates are connected by means of a corner angle bar.

The half beams in way of the hatchways are connected to the hatch coamings by means of angle collars, as shown in fig. 96.

When the strong beams at the ends of hatches are made up of a bulb plate and angle as shown in figs. 11 and 96, the beam knee is made in one of the following ways: either the beam is heated and the end turned down, and a piece of plate welded on the corner as shown in fig. 97, or else the bulb is chipped off the end of the bulb plate and a piece of plate or bulb plate welded on as shown in fig. 98.



Plan.

FIG. 98.—Bulb Plate Welded Knee.

It is also common to fit bracket plate knees to bulb plate beams, as shown in fig. 99.

In order that the bracket plate may fit close against the bulb plate, the bulb on one side must be chipped off.

The beam is necessarily cambered, and, like the ordinary beams, fits into the bosom of the frame as shown in fig. 98. In welded knees, preferably the bulb should be preserved right round the knee, and should finish upon the outside of the frame, as shown in fig. 13, as it affords both stiffness and strength to resist collapse under severe, transverse, racking stresses.

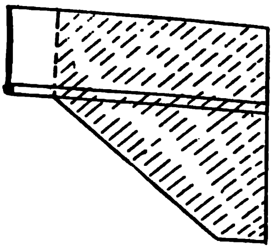


FIG. 99.—Bulb Plate Bracket Knee.

When we come to the upper deck beams in way of the engine and boiler openings, again the ordinary bulb angle beams are cut in way of the openings, with only an occasional specially strong beam run continuously from side to side of the vessel. These half beams are supported in a way similar to that explained for beams at hatch sides.

Stout steel coaming plates are fitted down over the beam ends, to which the half beams are attached by angle collars or lugs.

In the decks of most steam vessels, it is very common to see small hatch openings, say 2 or 3 frame spaces (about 4 or 6 ft.) in length, and 2 or 3 ft. in breadth (see fig. 129, deck plan). These are used for trimming coal into the bunkers, or, when at the ends of the vessel, as entrances to store-rooms (boatswain's, sail, etc.) When they open into coal bunkers only, the beams usually run through them without interruption, and the coal is trimmed through the spaces between the beams. In such cases, the beams are usually protected from damage by falling coal, by riveting a piece of convex iron to the top flange of the beam. In such cases, the coamings are simply erected upon the deck, there being no necessity to extend them further down.

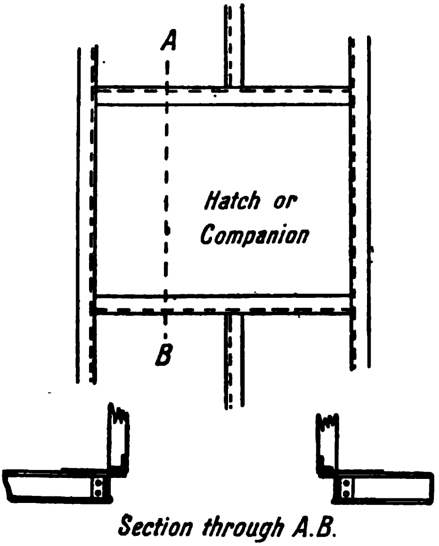


FIG. 100.—Beam cut for Hatchway or Companion-way.

Where the deck openings are entrances to store-rooms or cabins, it is usually necessary that such openings be entirely clear, and the beams are therefore cut at the sides of the hatchways, as shown in fig. 100.

The half beams may be supported by being attached to fore and aft coaming plates carried down below the beams, as previously described for large hatchways, or else a strong bulb angle or channel bar may be made to form the "fore and after" to carry the half beams, as shown in fig. 100.

A reduction is generally made in the thickness of the beams towards the vessel's ends. This reduction is usually made upon all beams which are less than three-fourths of the length of the midship beam. The reasonableness of this is easily explained. The shorter a beam or strut is made, preserving the same depth and thickness, the more rigidity does it possess, and the more resistance it offers to buckling. Hence the shorter end beams may be reduced $\frac{1}{20}$th in. in thickness, and still retain comparatively the efficiency of the beams at amidships.

Before leaving the upper deck beams, we may note that, had the vessel been of larger type, and channel bar beams been adopted, the knees would generally be formed of bracket plates, and would be constructed as shown in fig. 101, the bulb being, of course, substituted by the lower flange of the channel bar. In all other respects the knee formation would be as usual.

Turning to the forecastle (see fig. 11), we see that the beams consist of a bulb plate and two angles fitted to alternate frames. The knee to the bulb plate is made as described in figs. 97, 98, or 99. In the fore peak, the beams are similar to the forecastle beams. The plan in fig. 98 shows how the two beam angles fit against the frame and reverse frame.

The widely-spaced hold beams, as shown in the midship section, fig. 5, consist of bulb plates with two top angles and a covering plate. The larger flanges of the angle bars are placed horizontally, which necessitates that the

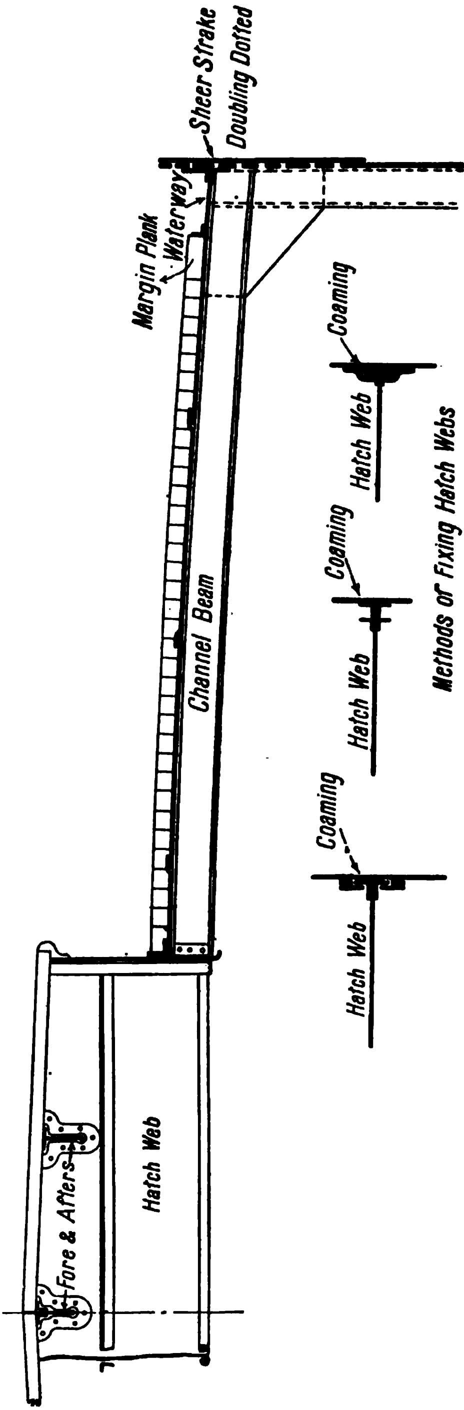


Fig. 101.—Section through Hatchway, showing Hatch Webs and Slides, Channel Beam Knees, and Sheer Strake Doubling.

covering plate be of the same width. The knee is formed like all other bulb plate beam knees.

The hold beams might have been as shown in fig. 102, in which case the knee may be either welded or bracketed.

Against the bulkheads we observe (fig. 11) that what are called semi-box beams are fitted. Fig. 103 will show more clearly how this strong beam is composed.

Semi-box beams are principally intended to act as stiffening to the bulkheads. We shall again refer to these bulkhead stiffeners when dealing with bulkheads. Suffice it for the present to say that the bulb plate knee is made by one of the methods previously described.

On coming to the engine space, however, we find a number of extra strong through beams, which are continuous from side to side of the vessel.

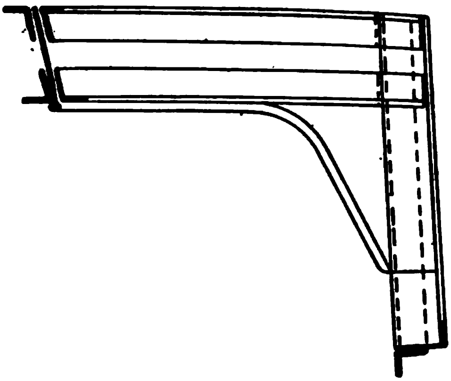


Fig. 102.—Strong Beam with Turned Knee.

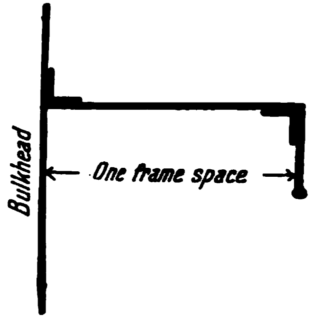


Fig. 103.—Semi-box Beam.

These are specially necessary when we remember that a large number of the ordinary beams are stopped in the way of the engine opening—these strong beams in some measure compensating for the loss of transverse strength. They consist mostly of bulb plates with four angles. The knees are of the usual construction. In elevation, the beam appears as shown in fig. 102, the plan being similar to fig. 98.

Sometimes two of these strong beams are fitted upon adjacent frames, and combined by plating them over—see strong beams in figs. 11, 12, and 14. We observe in the profile, fig. 11, that a steel deck is fitted all fore and aft to the upper deck. According to Lloyd's Rules, this vessel does not require more than a steel deck for half length amidships for structural purposes. Had the upper deck been sheathed with wood, the steel deck could have been gradually tapered off from the half length amidships, and the subsequent beams might have been of stronger section, and spaced upon alternate frames. However, the usual practice for cargo vessels has been followed in this case, and the steel deck made continuous all fore and aft, and unsheathed with wood. In many respects, this is preferable in cargo vessels.

When beams under wood decks are of tee bar, the knees are usually formed of bracket plates riveted on as for plain angles. When they consist of bulb plate and two angles, the knee is formed as already illustrated (see figs. 97, 98, and 99). When the beam is of butterly bulb section, the knee is usually made as shown in fig. 104.

The extremities of the beam are cut through the middle of the depth, and the lower part is turned down. A piece of plate is then welded into the space completing the knee form. Bracket knees might have been adopted, in which case the bulb would have to be chipped off one side. When steel decks are laid upon beams to alternate frames, beams of smaller section should be fitted to every frame at the sides of all hatchways and engine and boiler openings. See also description of beam knees to figs. 58 and 61.

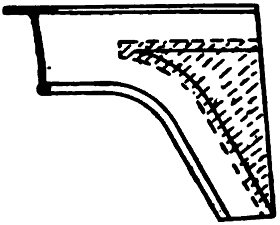


FIG. 104.—Butterly Bulb Welded Knee.

Lloyd's Rules give the following table for number and size of rivets in beam knees:—

Depth of Knee.	No. of Rivets.	Diameter of Rivets.
Under 17 inches,	4	$\frac{5}{8}$ of an inch.
17 and under 21	5	$\frac{3}{4}$,, ,,
21 ,, ,, 24	5	$\frac{7}{8}$,, ,,
24 ,, ,, 28	6	,, ,, ,,
28 ,, ,, 32	7	,, ,, ,,
32 ,, ,, 36	8	,, ,, ,,
36 ,, ,, 40	9	,, ,, ,,

The following beam knees should be at least three times the depth of the beam:—

1. In all steamers or sailing ships having one tier of beams.
2. To all beams on deep framing or web frames.
3. To all beams on deep tanks, peak tanks, or other water-ballast tanks.
4. To all beams of over 50 ft. in length.

Pillars.

A variety of kinds of bar iron or steel may be used to perform the tie and strut functions of pillars in ships (between decks and floors), and thus in addition to the plain round bar of circular section which is most commonly used, tee bars, either single or double fitted back to back, channel bars, single or double, and iron of I section, are now frequently adopted. One of the most recent types of ship pillars is made of stout steel plates bent into circular form and riveted like a mast. These, as shown on page 84 (see figs. 53, 54, and 55) are fitted in combination with other structural features, in order to dispense with the numerous round iron pillars ordinarily required. Then again, in recent "turret" steamers, circular steel tube pillars very widely spaced have been introduced (see figs. 43, 45, and 46).

Ordinary Round Iron Pillars.—Round iron pillars are made of malleable iron, and may be either solid or hollow. Comparing sectional area of material with sectional area, the hollow pillar is stronger and much more efficient than the solid one, though it has the objection of occupying more space, and being more costly to produce. The heads and heels of hollow pillars are solid.

According to Lloyd's requirements, all beams upon alternate frames (when the frames are spaced to rule) for at least three-fourths of the vessel's length amidships should be pillared. The beams for the remaining one-eight length at each end need only have pillars to beams upon every fourth frame. The pillars should be placed, as far as practicable, in the middle line of the vessel. In vessels with several decks or tiers of beams, in order that the pillars develop their full efficiency, they should extend from keelson or tank top to the upper deck, as nearly as possible in a vertical line, so as to form a continuous tie or strut.

The foregoing are only general rules, for it is impossible to rigidly follow them throughout the length of the vessel from stem to stern. For instance, in the engine and boiler spaces, such an arrangement is necessarily greatly interrupted, and stanchions have to be fitted where convenient. Again, in way of all hatches in the middle of the deck, the stanchions are placed on each side of the hatchway, generally somewhat more widely spaced (about six frames), as the deck has now two supports instead of one at the middle line. Under all permanent heavy deck weights, such as windlass, capstan, winches, deck houses, etc., additional pillars should be introduced, two or more generally being placed athwartships under such deck weights. Where hold beams are dispensed with—compensation in some form or other being introduced—the lower pillars, obviously, should be of greater diameter than would have been necessary had the hold beams been fitted, the greater length reducing the resistance to buckling, and increasing the danger of collapse.

In vessels of great breadth, the beams naturally require support between the ship's side and the centre-line pillars, hence quarter pillars are introduced (see fig. 13). Lloyd's Rules require that, for steam vessels of over 43 ft. and under 55 ft. in breadth, the quarter pillars be fitted to beams upon every fourth frame for half the vessel's length amidships, in addition to the centre-line pillars.

In pillaring a vessel, it is of the greatest importance to see that the heads and heels are efficiently constructed. Indeed, owing to the bad formation of the heads especially of some pillars, they never get the chance, as it were, *of developing their fullest efficiency.* In the making of pillar heads especially—which by the way, together with the feet, are made separately, and afterwards welded on to the pillar bar—the formation should be such that any thrust or compressive stress will be transmitted directly through the middle of the pillar, and not on one side (see figs. 105, 106, etc.); and the pillar head should bear hard against the beam or girder, so that the stress is borne by the material in the pillar, and not the rivets only. With such a formation of heads and feet, the rivets are only subject to stress when tensile strains are endured, *i.e.* when the pillar becomes a tie.

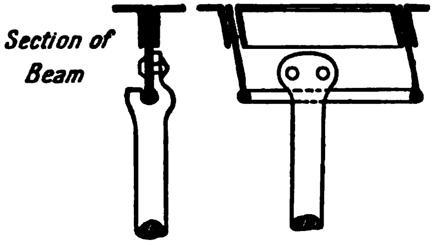


FIG. 105.—Connection of Pillar Head to Bulb Plate Beam.

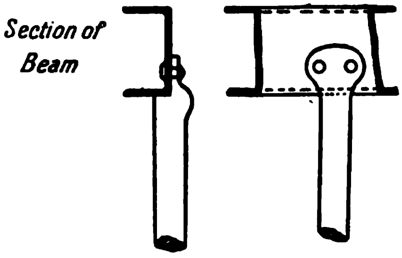


FIG. 106.—Connection of Pillar Head to Channel Bar Beam.

A great point to be kept in view in the pillaring of a ship is to see that the pillars do not act as *independent* struts or ties, but that they *distribute* their efficacy as far as practicable. Thus, especially in the case of vessels with steel decks, and bulb angle beams to every frame, to fix the pillar from the tank top or keelson to this comparatively flexible beam itself, would produce the tendency, when the pillar is subject to a compressive stress, to bulge up the deck in way of the pillar. To obviate this, a common practice is to fit a tee bar, or two angles back to back, to the under side of plain or bulb angle beams, and make the connection by fixing a short lug upon the bottom of the beam, as shown in figs. 108, 110, 111, and 14.

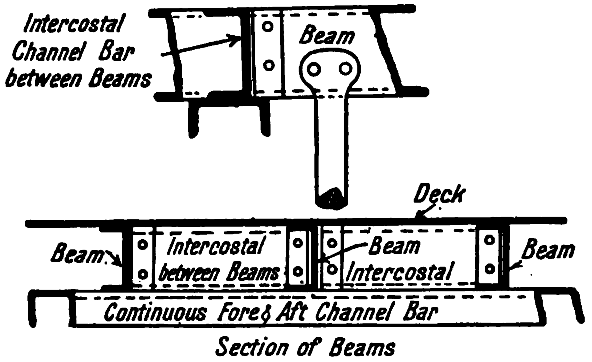


FIG. 107.—Showing an excellent method of supporting Steel Decks in combination with Pillars.

The pillar heads are then riveted to these fore and aft bars, under the alternate beams according to rule. The formation of pillar heads is shown in figs. 105 to 113. By means of the continuous longitudinal beam tie bars just referred to (figs. 107, 108, 110, 111, 113), the work done by the pillars is distributed to all the beams, instead of only to those under which the pillars are fixed. Similarly, where channel bar beams are fitted to every frame, the usual practice again is to tie the beams together, so as to distribute the pillar support. This is sometimes done by fitting a continuous channel bar to the under side of these beams (fig. 107). In this case, the pillars may be fitted alternately to one and the other of the continuous channel bar flanges on the under side of the beams, but it is preferable to attach the pillar head directly to the channel beam. As the section in fig. 106 points out, a much better supporting surface is obtained than could be got by riveting the pillar head to one of the flanges of the continuous channel tie bar. An even better system than this is seen in fig. 107, where, in addition to this continuous channel tie bar, intercostal channel bars are fitted between the beams, to which, by means of lugs, they are riveted; and also in fig. 113, where, in addition to the double angles on the under side of the beams, intercostal plates are fitted between the beams, and riveted to the deck. Such a system of fitting a substantial girder to beams and deck, especially if bracketed to the bulkheads at the end of each hold compartment, affords great support and stiffness to the deck, and permits of the hold pillars (if of increased sectional area) being

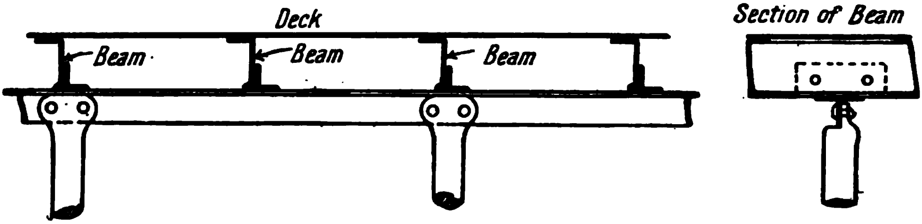


FIG. 108.—Connection of Pillar Heads to a fore and aft Tee-bar tie under Beams.

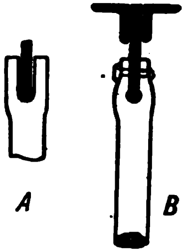


FIG. 109.—Another form of Pillar Head.

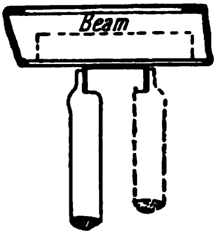


FIG. 110.—Arrangement for fitting Hold Shifting Boards between Pillars.

spaced much more widely than is usual. The advantage of such an arrangement from a stowage of cargo point of view is apparent. This applies equally to fig. 107.

The formation of pillar heads for channel beams is shown in figs. 106 and 107. Where, however, the beams are fitted on alternate frames, and are therefore much more rigid, owing to their greater depth and sectional area, than would be the case for beams on every frame, it is usual to fit the pillar heads directly on to the beams, no continuous tie being fitted to the under side of such deep beams (see figs. 105 and 106). When shifting boards must of necessity be fitted down the middle of a hold to prevent cargo moving, the common practice is to place them between round iron pillars arranged as shown in fig. 110. In this case we have a continuous channel tie on the under side of the beams to which the alternate pillars are fitted to first one and then the other

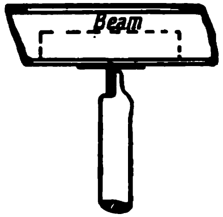


FIG. 111.—Double Angle Beam Tie, and Pillar-head Connection.

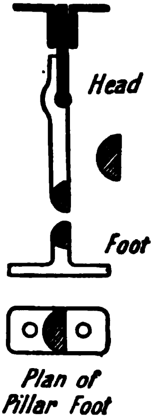


FIG. 112.—Pillar in Cabins.

FIG. 113.—Another excellent method of supporting Steel Decks in conjunction with Pillars.

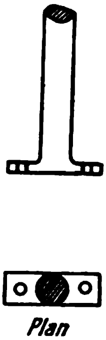


FIG. 114.—Ordinary Pillar Foot.

flange. Instead of the channel bar, two angle bars are sometimes used for the same purpose.

All pillar heads, such as those we have just described, should be connected by at least two rivets. A pillar head not very commonly adopted, but which requires only one rivet, is seen in fig. 109. The head is formed as shown in A. This head, on being heated and placed under the beam, is closed up as in B, and secured by one rivet. Where pillars are required to be portable, the heads are fastened by means of nut and screw bolts instead of rivets.

The formation of pillar feet, connected to a centre keelson standing on ordinary floors, is shown in elevation and plan in fig. 114. The connection here is by means of two rivets. Where, however, the pillar feet come over the centre through-plate in a vessel with a double bottom, the feet are formed and connected as in figs. 115 and 116. In fig. 115 a socket is formed for the pillar foot, either between two flanged plates, or two angle bars riveted on to a base plate through which the connection is made to the tank top. In the alternative method, fig. 116, the pillar foot is connected to a piece of tee bar which is riveted through the tank top plating and upper bars of the centre keelson. The pillar feet in a 'tween decks where a steel deck is laid, should be riveted through the deck plating and the beam. But a better arrangement is to fit the feet on to a short piece of tee bar, long enough to take three rivets, somewhat similar to the sketch in fig. 116. Where, however, no steel deck is laid, and the beams are upon alternate frames, the pillar feet may be formed as in fig. 114, and attached directly to the beams. Or better still, by fitting a continuous tie bar, or two angle bars riveted back to back, a more satisfactory distribution of the work of the pillar is obtained. These angle bars, if made large enough in their horizontal flanges, will form a substitute for the tie plates which in any case would be necessary upon beams on alternate frames where no steel deck is laid. Where pillars are required to be portable,

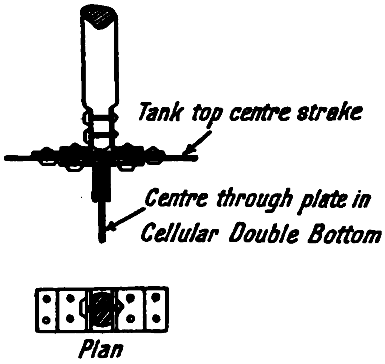


FIG. 115.—Pillar Foot on Inner Plating of Double Bottoms.

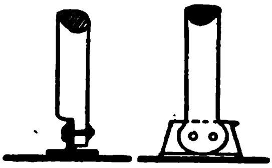


FIG. 116. —Showing connection of Pillar Feet to Steel Decks, or Inner Plating of Double Bottoms.

which is often necessary at hatch sides, the feet may be made in any one of the three ways shown in figs. 117, 118 (A and B).

Fig. 117 shows the pillar foot dropped into a cast-iron ring, which is riveted to the deck or tank top plating as the case may be. A half-inch or five-eighths nut and screw bolt is passed through the cast-iron ring and pillar foot as shown. Fig. 118, B, shows the pillar foot placed in a horseshoe angle bar, and is kept in position by a preventive nut and screw bolt. In this method, the pillar only performs the function of a strut. As shown in the diagram 118, A, the foot of the pillar is permanently riveted, the upper part only being portable, with a nut and screw bolt means of connection as shown.*

The heads and heels of all ordinary pillars fitted in cargo vessels should be connected to the structure by at least two well-formed rivets. But those fitted in deep water-ballast tanks should be connected by means of three rivets.

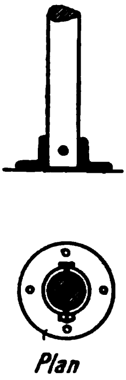


FIG. 117.—Portable Pillar Foot.

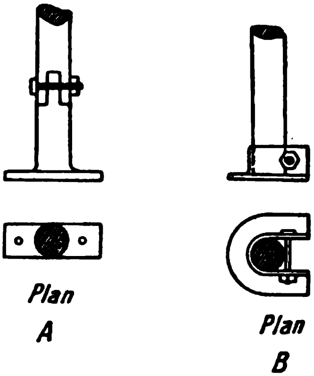


FIG. 118.—Portable Pillars. Arrangement of Feet.

Channel and Tee Bar Pillars.—Where pillars are constructed of tee bars or channel bars (either single or double), or of I section, they are connected to the beams at their upper extremities, and to the tank top at their lower extremities, by means of bracket plates (see figs. 42, 49, 54, and 55).

Large Round Plate Pillars and Steel Tube Pillars—substituting centre-line hold and quarter pillars—have already been dealt with on page 84, "Some New Features in Modern Shipbuilding" (see figs. 53, 54, and 55; see also page 72, "Turret Steamers," and figs. 43, 45, and 46).

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* These portable pillars are not as efficient as well-formed fixed stanchions, but as only very few are usually required (generally at the side of hatchways), no serious objection need be offered to them.

When cabins are fitted in a 'tween decks, the ordinary round pillar is sometimes objectionable, and in many cases half round or flat iron stanchions, as in fig. 112, are substituted.

Keelsons and Stringers.

Keelsons.—The most important keelson in the ship is the centre keelson, and although, according to the particular mode of construction adopted, it varies considerably in form, its function is always the same, viz., to afford longitudinal strength along the bottom of the ship. The centre through-plate keelson and side keelsons, in vessels with double bottoms, have been referred to on several occasions and fully described already (see figs. 13, 36, etc.).

Fig. 119, A and B, illustrate what are known as centre keelsons standing upon ordinary floors, the vessel in the diagrams having a bar keel. The principal parts of the keelson, A, are a deep vertical plate with two large angles on the bottom connected to the reverse frames and the lug piece shown; and, on the upper edge, two similar large angles with a flat plate, known as a rider plate, covering the full width of the top flanges. The large keelson angles have one flange exceptionally large, while the other is considerably smaller. The large flanges are arranged vertically for the bottom bars, and horizontally for the top bars. The butts of both centre plate and rider plate should be either strapped or overlapped, and treble riveted. The butts of the angle bars should be connected by bosom pieces with at least three rivets on each side of the butt. The butts of vertical plate, rider plate, and angles should be kept as clear from each other as practicable. The centre keelson in B, fig. 119, is identical with A, with the exception that, being for a larger vessel, a thick foundation plate is riveted to the floors immediately under the keelson to which the bottom angles are connected.

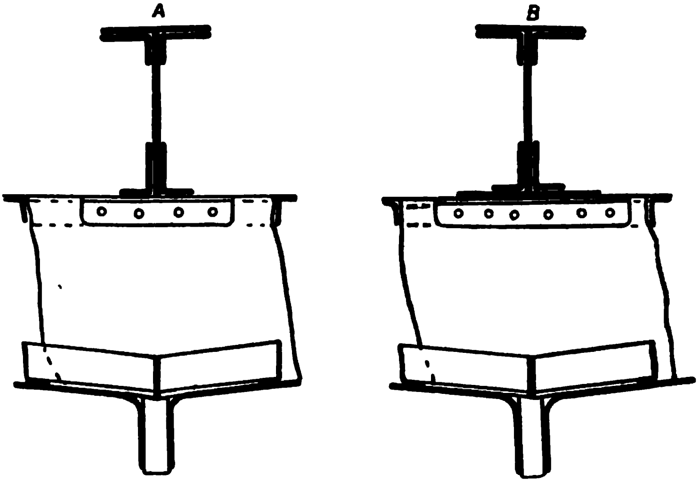
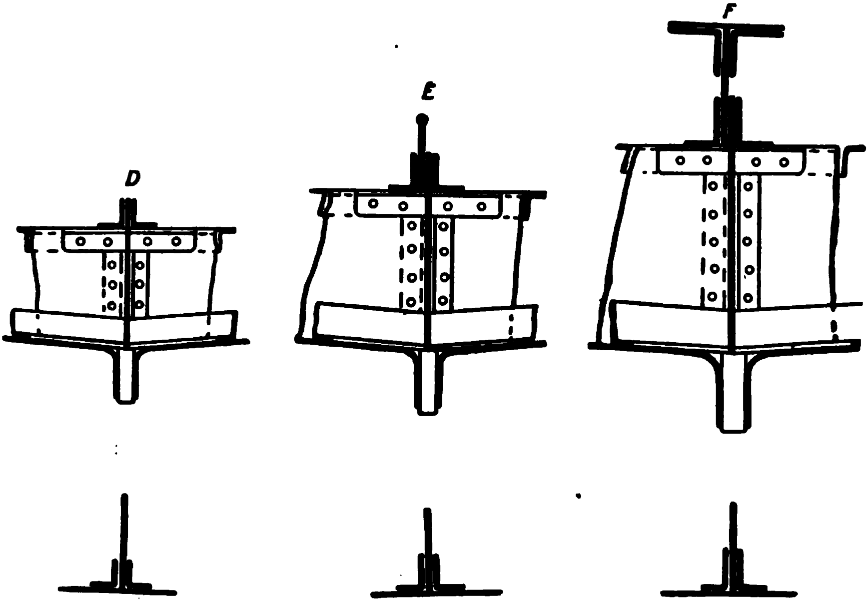


FIG. 119.—Centre Keelsons standing upon Ordinary Floors.

Fig. 120, D, E, F, illustrates another type of centre keelson, known as a middle line intercostal keelson. As the diagrams show, the vessel has ordinary floors and a bar keel. The keelson in D, which is for a very small ship, has two continuous angles on the top of the floors, with intercostal plates fitted between the floors extending from the top of the keel to the top of the keelson angles. The intercostal plates are connected to the floors by single angles as shown. Figs. E and F are similar keelsons for vessels of larger size. The intercostal plate in each case extends to the top of the lower keelson angles.

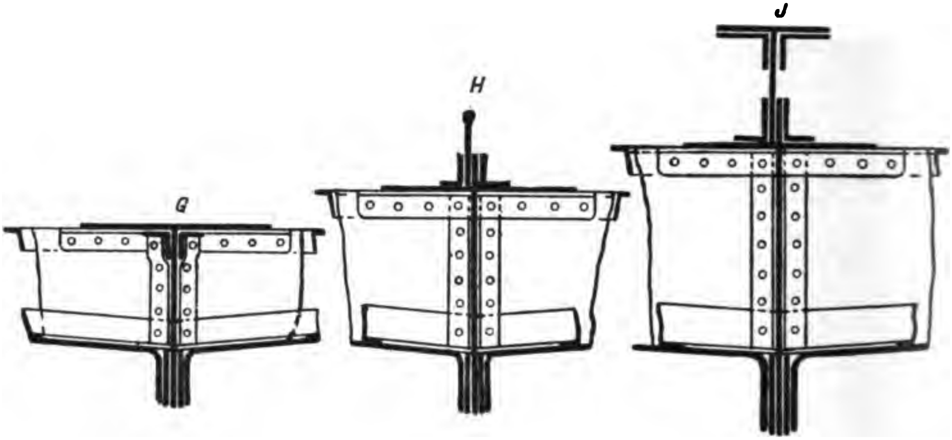
Fig. 121, G, H, and J, illustrates the centre through-plate keelson in vessels having side bar keels. Here, again, the floors are of the ordinary type. In G, the centre through-plate extends from the bottom of the keel to the top of the floors. Along its upper edge, and riveted to the floors, is a broad thick plate, connected to the centre through-plate by the two large angles shown on its upper edge. It will be seen how admirably this plate binds both floors and keelson together. Fig. H, which is for a larger vessel, shows the centre through-plate extending to the top of the keelson angles. The foundation plate upon the floors under the keelson angles is necessarily in two pieces, one on each side of the centre through-plate. Fig. J is identical with fig. H, excepting that, being for a still larger vessel, the part of the keelson above the floors is somewhat modified.



Showing Intercostal Plates fitted upon Flat Plate Keels.

FIG. 120.—Intercostal Centre Keelsons.

Side Keelsons (fig. 122).—All vessels should have keelsons upon the floors at the lower turn of the bilge. These may vary in section as shown in fig. 122, P, Q, M. P is two plain angles fitted back to back. Q is the same as P with a bulb plate between. M is the same as Q, excepting that, in addition to the bulb plate, an intercostal plate is fitted from the top of the angles to the bottom of the floors, and connected to the shell by another angle bar as illustrated in fig. L. The bulbs and intercostals are often extra strength introduced on account of a vessel's extreme proportions. Between the centre keelson and the bilge in very small vessels, a thin plate is fitted intercostally between the floors to which it is connected. The principal function of this plate is to check the wash of bilge water when the vessel is rolling. Hence it is called a wash plate (see K). In larger vessels a double angle side keelson is required extend-



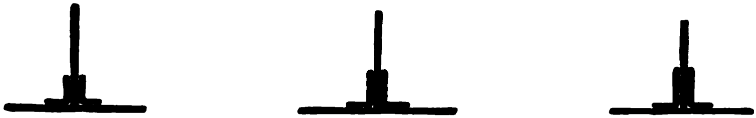

Showing Centre Through-plates fitted upon Flat Plate Keels.

FIG. 121.—Centre Through-plate Keelsons for Vessels having Side Bar Keels.

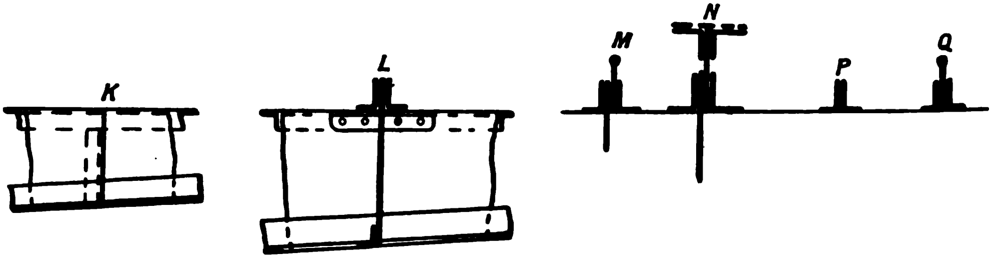


FIG. 122.—Side Keelsons.

ing across the top edge of the floors, with sometimes both a bulb and an intercostal plate between them (fig., L and M). In still larger vessels, or where the proportions are very extreme, a side keelson with an intercostal plate, as shown in N, is sometimes required.

In all cases wherever centre, side, or bilge keelson angles, or horizontal plates, pass over the floors, the connection is made by short lug bars in addition to the ordinary reverse frames.

Stringers.—Stringers, in many respects, are very similar to keelsons.

Fig. 123, R, S, T, U, V, illustrates a number of types which are regulated by the depth and proportions of the vessel. As already pointed out for keelsons, angle lugs are again required in addition to the reversed frames, in order to get a good connection to the transverse framing. Stringers for vessels with deep frames are illustrated in figs. 13, 58, and 60. Keelsons and stringers may be carried uninterruptedly through all the bulkheads, in which case well-formed angle collars are necessary in order to ensure watertightness (see fig. 124, F). Where the stringers are cut at the bulkheads, which is the simpler way of obtaining watertightness, the continuity of their strength is maintained by fitting large bracket plates.

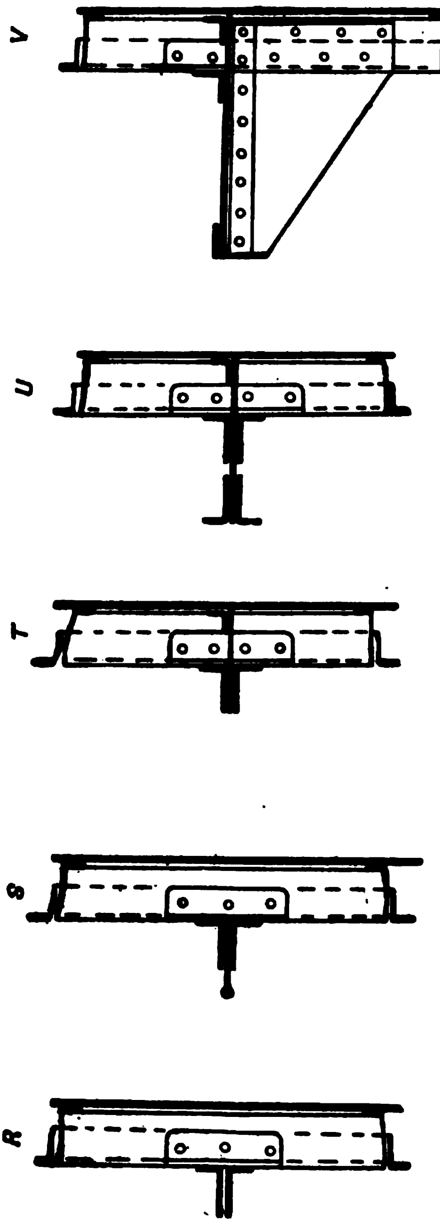


FIG. 123.—Forms of Side Stringers. (See also the very compact form of side stringer illustrated in figs.40, 48, 45, 52, 58, 60, etc.)

Fig. 123, A, illustrates a side stringer such as is shown in the midship section of fig. 13, cut at the bulkheads and connected by large brackets, which extend to the heel of the bulb angles forming the stringers.

Stringers and keelsons should be carried as far forward and aft as practicable, and the ends of stringers should be connected to a breast hook —a horizontal plate binding the two sides of the vessel together.

Bulkheads.

Steel and iron bulkheads are walls of plating extending transversely from side to side, or longitudinally, throughout the whole or part of the length of a vessel. They are valuable as a means of dividing the large volume contained in the hull of a ship into a number of separate compartments, and in entirely shutting off the engine and boiler spaces from the hold spaces, a feature of very great importance where inflammable cargo is carried in the adjoining compartments.

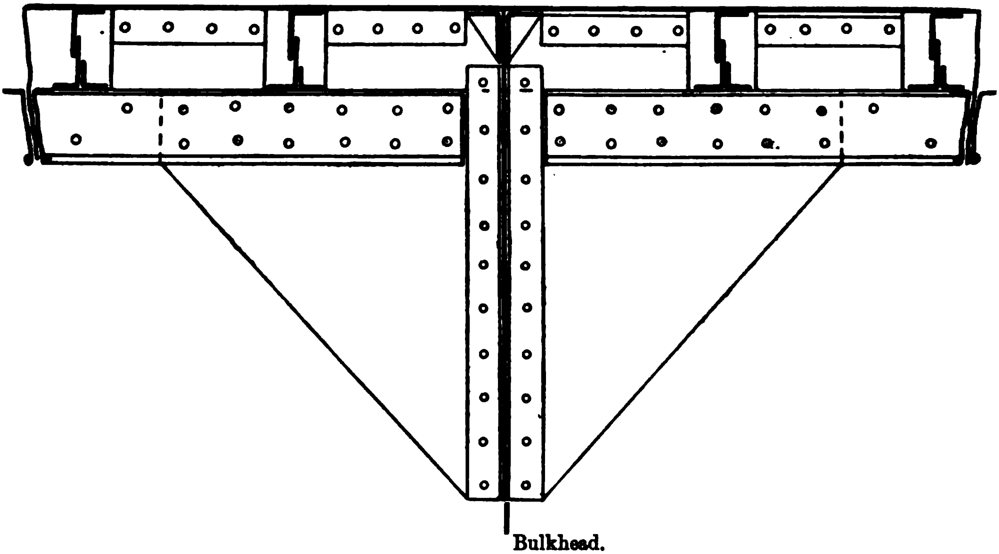


FIG. 123, A.—Stringer cut at a Bulkhead, and connected by large Brackets.

But their principal function lies in affording structural strength and—in the case of passenger steamers, where they are usually spaced closer than is the practice in cargo steamers—safety also in the event of the shell being perforated, and water finding access. Long shallow vessels are particularly liable to evince longitudinal weakness. In such vessels, great additional strength and stiffness is obtained by fitting a continuous longitudinal bulkhead all fore and aft down the middle of the hull and connecting it to, or making it form part of, a centre keelson on its lower extremity, and attaching it to the deck at its upper edge.

Transverse bulkheads afford great support to both the longitudinal and the transverse framing of a vessel, and contribute in a large measure to the general strength. When transverse bulkheads are well constructed and stiffened, and made perfectly watertight, they may render immense service in case of collision or perforation of the shell plating, by confining the water to one of the compartments into which they divide the hull. They must, therefore, be securely connected to the shell plating, decks, and bottom of the vessel, and, in addition, the plating must be of sufficient thickness, and stiffened and supported in such a manner as to withstand the pressure of water which would come upon it in the event of such a compartment being perforated and flooded. A longitudinal bulkhead, while it may provide valuable and necessary strength to the hull, may also be a source of danger if made watertight, excepting in the case of vessels carrying liquid cargoes; for in the event of a compartment on one side of such a bulkhead becoming flooded, the loss of buoyancy may produce a positive danger, which would not have existed had the water been able to fill the compartment from one side of the vessel to the other. It is therefore advisable, under some circumstances, to so construct a longitudinal bulkhead that water could find ready access through it.

All classed vessels built in accordance with ordinary practice are required to have a certain number of transverse bulkheads, which number depends in steamers upon the length. The rules require that all screw steamers have at least four watertight bulkheads, one at each end of the engine and boiler space, and one at a reasonable distance from each end of the vessel.

The necessity and importance of these bulkheads is fairly obvious. The importance of having the engine and boiler spaces thoroughly isolated from the remaining portions of the hull has already been referred to. The fore-end of vessels being likely to suffer most severely in the event of collision, and, in addition, being specially subject to the thumping action of the waves in steaming against head seas, as well as the tendency to pant when driven at considerable speed even in smooth water, all clearly show the necessity of a watertight bulkhead at a moderate distance from the stem, which should not be less than one-twentieth of the vessel's length from the stem in order to be an effective safeguard should leakage occur from any of these causes.

At the after end of the vessel (especially in very large ones) we have an enormously heavy stern frame attached by means of long rivets to what are, in comparison, thin plates composing the shell, and which, in addition, is subject to considerable vibration caused by the propeller, especially when racing in heavy weather. Again, the breaking of a tail shaft often fractures the stern tube, and hence the possibility of leakage, and the necessity of a watertight bulkhead at a reasonable distance from the stern post. Where the shaft passes through this bulkhead, the watertightness is assured by fitting a stuffing box.

When the length is 280 ft. and above in steamers, an additional bulkhead is required by Lloyd's midway between the collision and the foremost engine space bulkheads; and when the length reaches 330 ft. and over, another bulkhead is required in the after hold, situated therefore between the aftermost bulkhead in the vessel and the after engine room bulkhead.* These additional bulkheads greatly assist in stiffening the framing of the vessel, and they improve the chances of the vessel remaining afloat in the event of one of these compartments becoming flooded. All transverse bulkheads in one, two, and three deck vessels should extend to the height of the upper deck, and in spar deck vessels to the height of the spar deck. In the case of awning deck vessels, all the bulkheads should extend to the height of the main deck with the exception of the collision bulkhead, which should extend to the awning deck.†

As we have pointed out, the fore end of the vessel being the most vulnerable, and the loss of buoyancy at the extreme ends of a vessel through perforation of the shell plating producing greater change of trim than the loss of as much and even more buoyancy nearer amidships, the necessity of continuing the collision bulkhead, even in an awning deck vessel, to the weather deck, will be clear. To carry a watertight bulkhead in a direct, uninterrupted vertical plane from the floors to the prescribed height, is not always convenient, nor is it absolutely necessary. It may be recessed or stepped backwards or forwards at some place in its height, and then carried to the required deck. No objection can reasonably be lodged against this so long as the workmanship is thoroughly efficient, and the strength and watertightness maintained. See also remarks, page 73, and fig. 47, relative to omission of transverse bulkheads other than collision and machinery.

In sailing vessels, only the collision bulkhead is required by Lloyd's, though many owners prefer to introduce additional bulkheads for structural reasons and for the sake of the convenience of having the hold space divided into separate compartments for the stowage of cargo.

In arranging the plates of a bulkhead, they are disposed either with their lengths vertical, or horizontal. Fig. 124 is a sketch of a bulkhead with the plates arranged horizontally. As the figure shows, the vessel has two steel decks, and as the continuity of a steel deck is vastly more important than the continuity of the bulkhead, the deck suffers no interruption, but the bulkhead is severed at the lower steel deck, and continued again in the 'tween decks.

A watertight bulkhead is connected to the shell plating by means of

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* Vessels over 400 ft. require 7 bulkheads.
,, 470 ,, 8 ,,
,, 540 ,, 9 ,,

† In awning deck and shelter deck vessels, partial bulkheads or web frames for the support of the topsides should be fitted in the 'tween decks immediately above the main bulkheads.

double angle bars of the size of the frames, between which angles the bulkhead plating is fitted; see horizontal section of bulkheads, fig. 124, A and B (or a large single angle double riveted may be adopted). As the watertightness must be maintained from lower to upper extremity, a connection to the steel decks is usually made by means of double angle bars of about the size required for reversed frames (see E, C, and K, fig. 124). Should the vessel have a double bottom, the connection to the tank top is also usually made by means of double angles of the size already mentioned, D, C, K, fig. 124. While the overlapping of the edges and butts of the plates gives a certain amount of stiffness to the area of plating, yet this is totally inadequate to provide the strength required in carrying even bulk cargoes, such as grain, much less to withstand the pressure which would accrue, owing to a head of water, in the event of a hold space becoming flooded to any considerable extent. An intelligent arrangement, therefore, of well-disposed stiffeners is necessary. Lloyd's requirements for the stiffening of transverse bulkheads are as follows:—On one side of the bulkhead the stiffeners are angle bars of the size of the frames spaced not more than 30 in. apart. If the vessel is built with ordinary floors, these stiffeners should be continued well down over the floor plate (see E, fig. 124). If the vessel have a double bottom, these stiffeners should be connected to the inner bottom plating by means of plate brackets (D, K, fig. 124). Additional vertical stiffening is given to all bulkheads of large breadth in the form of webs of plating extending from the centre keelson or top of floors, or from the tank top in vessels with double bottoms, to the height of the lowermost tier of beams (A and C, fig. 124). When the bulkhead is 36 ft. and under 45 ft. in breadth, one such vertical web stiffener is required, and, in the case of vessels with ordinary floors, would be riveted at its lower extremity to the top of the centre keelson. When the breadth of the bulkhead is 45 and under 55 ft., two such vertical webs are required. Bulkheads of 55 and under 60 ft. in breadth require three vertical webs. In order to support the vertical stiffeners, and to give additional rigidity and strength to the bulkhead, horizontal stiffeners are fitted to the other side of the bulkhead, and spaced below the lowermost laid deck, about 48 in. apart. These stiffeners, in all vessels of less than 40 ft. in breadth, may be of angle bars of the size of the main frames; but when the bulkhead is of 40 ft. breadth and above, the horizontal stiffeners should be of bulb angles of at least the size required for a steel or iron deck fitted to the same vessel.

These bulb angle stiffeners should be well connected to the vessel's side by means of plate brackets.

In all vessels requiring two or more decks, where the lowermost deck has been dispensed with by compensation in some form or other, or when such a deck is not laid so as to give longitudinal support to the bulkhead, Lloyd's require that a semi-box beam, E, C, and K (see fig. 124), be fitted across the bulkhead where the lower deck would have afforded its support;

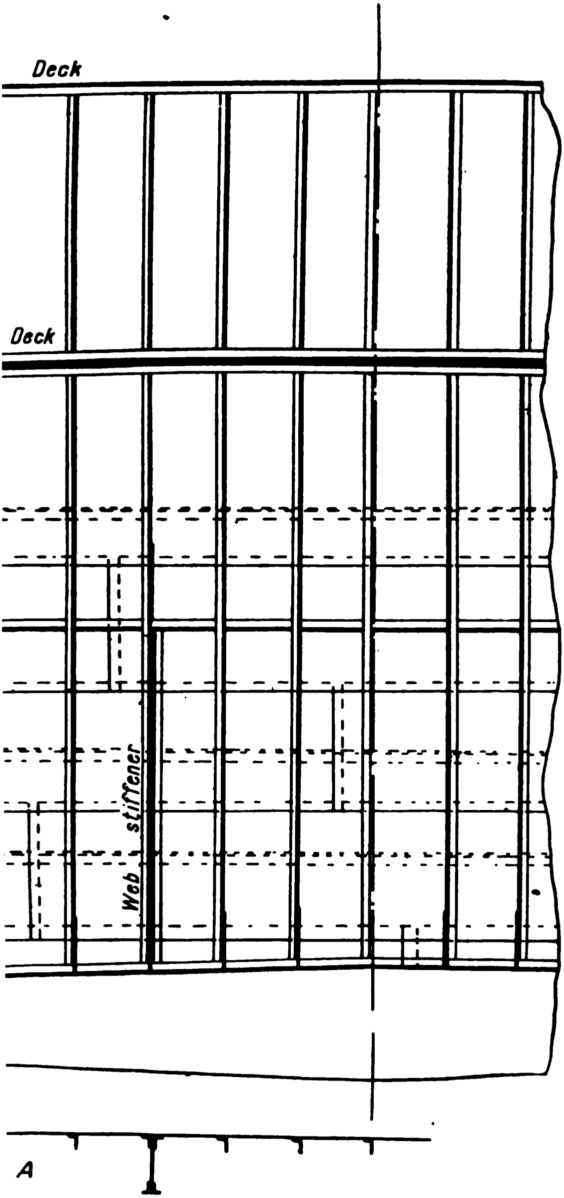
or, if there be a side stringer in this vicinity, the semi-box beam may be fitted so that its ends may be attached to the stringer. The breadth of the semi-box beam is one frame space, and the bulb plate or channel bar or bulb angle forming the side of the beam away from the bulkhead should be connected to the frame upon which it comes by an efficient knee. (See also fig. 103.) The fore peak, as we have already noticed, being especially liable to damage, and the compartment to being flooded, special attention is always given to rendering this bulkhead thoroughly efficient under all circumstances of emergency. Hence, Lloyd's require that the horizontal stiffeners should be of bulb angle of the size of iron and steel deck beams, and connected to the vessel's sides by plate brackets. Where, however, the fore and after peaks are intended to carry water ballast, and indeed in all deep tanks situated either at the ends of the vessel, or in the region of amidships, the vertical stiffeners on the bounding bulkheads should always be of bulb angles or channels of at least the size just mentioned (K, fig. 124). The stress upon these bulkheads is very severe when the tanks are full, but where, through neglect or carelessness, vessels are allowed to proceed to sea with these tanks only partially filled, the damage to the bulkhead may be enormous.

Owing to the pressure of water upon a bulkhead in a flooded compartment being greater on the lower half than upon the upper, it is the practice to make the plating in the lower half $\frac{1}{16}$th or $\frac{1}{20}$th in. thicker than in the upper. The riveting of both lap edges and lap butts of bulkhead plating is usually made by a single row of rivets, excepting in the connection of the main bulkhead plating to the deep floor plate which forms the lower part of the bulkhead in vessels with ordinary floors, and the coaming plate in vessels with double bottoms (see fig. 124). This latter connection should be made by a double row of rivets. The spacing of bulkhead rivets should be about 4 diameters apart from centre to centre. The rivet holes in the transverse flanges of the double angle bars connecting the bulkhead to the shell plating should also be about 4 diameters apart from centre to centre.

All bulkheads must be caulked to ensure watertightness. This, however, it is only necessary to do upon one side of the bulkhead.

In making the connection of the double angle bars round the bulkhead to the shell plating, the rivet holes in the fore and aft flange of that bar fitted upon that side of bulkhead which is caulked should be spaced about 4 to 4½ diameters apart. The rivet holes in the fore and aft flange of the other bar which is upon the other side of the bulkhead should be spaced to the ordinary spacing in frames, viz., 7 to 8 diameters apart.

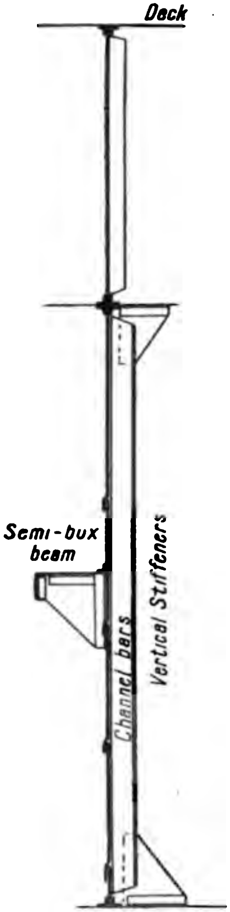
As will be shown when we come to deal more particularly with shell plating, the most perforated transverse section of the shell is in way of the line of rivet holes, spaced, as we have stated, 4 to 4½ diameters apart on the caulked side of the bulkhead. Some compensation must therefore be made for this excessive weakening of the shell plating. This is done by fitting what are called bulkhead liners, or doubling plates.



'ertical stiffeners

K

Illustrating another arrangement of stiffening bulkhead



lap, and the butts for half length amidships should be double riveted, and single at the ends * (fig. 129).

While steel or iron decks are often fitted in preference to wood decks, they are often an indispensable structural part, required on account of the vessel's size and proportions. The longitudinal stresses being most severe over the midship length, it often happens that a steel deck may only be required for the half length amidships, in which case it should be gradually tapered off from the middle line towards the stringer plates. For the same reason, when the deck plating is $\frac{7}{20}$ths of an inch or more in thickness, at amidships, it may be slightly reduced in thickness towards the ends. Owing to the superiority of iron in resisting the attacks of the weather, and therefore suffering less from corrosion, such parts of deck plating as are exposed to the weather are commonly of iron, and elsewhere (where covered) of steel. In order to obtain equivalent strength, the iron plating should be somewhat thicker than the steel.

Of necessity, numerous openings are cut through the decks of all vessels—engine and boiler openings, hatches, companions, etc. This naturally reduces the strength of the deck, and compensation in some degree must be provided by thicker deck plating, or doublings, in the way of such openings. As the deck is no stronger than its weakest section, a certain percentage of the maximum transverse strength should be maintained. Thus, over the midship half length, the aim should be to secure, especially in the strength deck (upper deck), 80 per cent. of the maximum sectional area of the plating.

Fig. 129 shows the upper deck plan of the vessel whose midship section and longitudinal profile are illustrated in figs. 12 and 46. The diagram shows that, as far as possible, butts of adjacent strakes have been kept at least two frame spaces clear of each other, and alternate strakes at least one frame space. The plating of the deck at the sides of hatches and engine and boiler openings has been increased in thickness; doublings have been fitted at the corners of the openings for all large hatchways and for engine and boiler casings, as, especially where such corners are rectangular, there is the tendency, owing to the severity of the racking stresses in such localities, to rupture. Doublings have also been fitted at the sides of small bunker hatches. When it is intended to sheathe a steel deck with wood, the strakes of deck plating should be arranged alternately, one in, one out (see wood decks, fig. 36). A slight reduction necessarily takes place in the thickness of the wood deck over all outside strakes of plating. The wood deck over the inside strakes should bear hard down upon the plating, and upon no account should the objectionable practice of fitting wooden packing pieces be permitted, in order to save thicker planking, or the trouble of efficient fitting. A sheathed steel or

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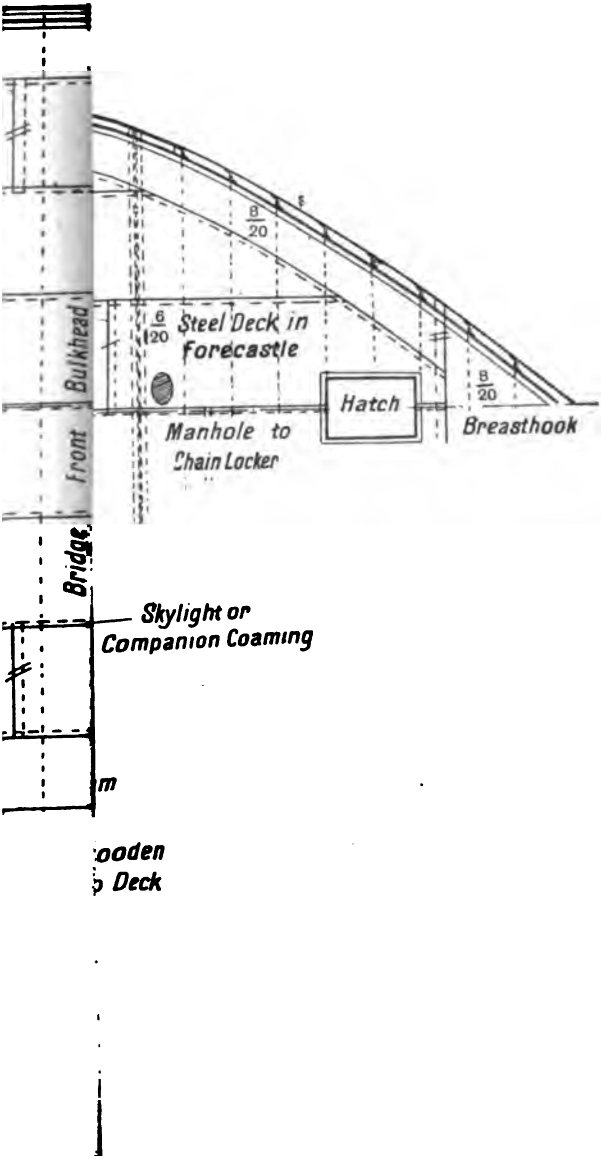
* The overlaps of the butts of deck plating should look towards amidships. This (in vessels having sheer) prevents water lodging at the butt, and eventually injuring the caulking.

11,



8/20
6/20
Steel Deck in Forecastle
Bulkhead
Front
Hatch
8/20
Breasthook
Manhole to Chain Locker
Bridge
Skylight or Companion Coaming
m
ooden
Deck

iron deck should be well coated with reliable bitumastic composition or vegetable tar, for it will easily be seen what havoc may be wrought in the deck plating in the event of water finding its way through defective caulking in any seam or butt in the deck planking, an occurrence not at all infrequent. When the deck plating is unsheathed, it is preferable to arrange the strakes of plating each in and out like the slates upon a roof, as shown in the midship section, figs. 7 and 11. By this arrangement, water on deck naturally flows towards the waterways, and finds its way through the scuppers. Every possible means should be taken throughout the vessel to prevent the lodgment of water, if the structure is to be preserved from corrosion and decay.

All steel decks should be thoroughly watertight, hence every seam and butt must be properly caulked. In the case of upper decks uncovered by erections, the watertightness against the shell plating is easily secured by the gunwale bar, which also ought to be caulked against the shell and the deck. In the way of the erections, and in 'tween decks, where the frames pass through the stringer plate, the watertightness is obtained by fitting a continuous angle bar along the toe of the transverse flange of the frame, to which it is connected either by an angle lug, or the extended reverse bar, and an intercostal angle between the frames against the shell; the space between these two angles is then filled with good cement.

Where the most satisfactory and reliable method of effecting water- or oil-tightness is desired in a deck through which the frames extend, either joggled bars are fitted round all the frames, or else the frames are cut and a continuous angle attached to the shell and deck stringer plate, as shown in the 'tween decks of the midship section of the oil steamer, fig. 64. In this case the continuity of the strength of the frames is maintained by means of bracket plates to the decks. When the continuity of a steel deck is interrupted, as in the case of the raised quarter deck type, where the main deck extends for a certain length of the vessel, and is then raised several feet, after which it is known as the raised quarter deck, compensation for the break must be made. This is done by overlapping the decks (see fig. 12), excepting in very small vessels, when the main and raised quarter decks are bound together by large bracket plates well riveted to the bulkhead at the break.

Wood Decks.—When wood decks are laid upon the beams, they ought to be scored out on the under side in way of all tie and deck plates. No packing pieces should be allowed. The butts of the deck planking should be carefully arranged, there being at least three clear shifts between any two butts in the same beam space. Beams under wood decks are usually fitted on alternate frames, and are generally of bulb plate and double angles or tee bulbs. The butts of the deck planks should always come on the centre of the beam or on a deck plate. The butts are practically always of the vertical kind as shown in fig. 129, A.

The fantastic butts sometimes illustrated are seldom, if ever, adopted in mercantile shipbuilding practice. When the deck planks are 6 in. in width or under, a single through-bolt through every beam is sufficient. When the planks are above 6 in. and not more than 8 in. in width, there should be one through-bolt and a short screw-bolt on the under side in every beam. All planks over 8 in. in width should be fastened with two through-bolts through every beam. Through-bolts should be nut and screw. It is preferable that all bolts be galvanized. They should be properly sunk in the deck with their heads well bedded in oakum and white lead, and their heads should be carefully covered with turned dowels also bedded in white lead or some suitable composition (see fig. 129, A, for sketches of bolts, dowels, etc.).

The beams should be well painted with good red lead paint before the decks are laid; and in some cases, in order to preserve the appearance of the deck, by preventing discolouring due to rust water oozing through the butts, felt, dipped in red lead, is placed under the butts. In very high-class work, zinc slips are fitted on the beams under the butts.

It is always better that the wood deck, alongside of iron deck-houses, waterways, hatch coamings, etc., be of either teak or greenheart. All seams and butts should be caulked with oakum, and filled in with marine glue or some other suitable composition. When openings are cut through the deck for companions or skylights, care should be taken that the deck planks next to the openings are so secured as to prevent their yielding, due to the pressure caused by caulking. An excellent method of fitting an angle bar round such openings is illustrated in fig. 129, B. For the same reason, an angle bar should be fitted alongside all waterways.

All wood for decks should be free from sap, shakes, and knots, as far as possible. It should be well seasoned, and of good quality. Yellow pine, pitch pine, and teak are among the principal timbers used, and not less than six months should be allowed for seasoning.

Teak decks, which are very durable, may be of less thickness than would be required for pine decks. In laying a deck, care should be taken that the weather side (the hard side) be uppermost, with the heart downwards.

When a wood deck is laid upon a steel deck, the butts and fastenings may come between the beams.

In order to get rid of the water which on weather decks naturally drains into the waterways, it is necessary that scuppers be fitted. Fig. 129, C, D, E, and F, shows four different kinds of scuppers.

C shows a small aperture, 3 in. or 4 in. in length, cut through the sheer strake immediately above the deck stringer plate. The gunwale bar is preserved continuously as shown.

In F, owing to the gunwale bar being cut at the scupper, a compensation bar is fitted on the under side of the stringer plate.

D and E are forms of scuppers adopted in bridges, or poops, or 'tween decks, water finding its way into these through a perforated brass plate fitted into the stringer plate, while storm valves are usually fitted to the shell exit to prevent water finding its way into the ship through the scuppers; or, in some cases, screwed lids are fitted on to the perforated deck plate for the same purpose.

Outside Shell Plating.

While the skin or covering over the framing of all vessels is an indispensable part of the structure, in iron or steel vessels the outside shell plating, while performing the work of a watertight skin, is also the principal structural item in the ship girder. A steel ship being composed of a vast number of minor girders, each contributing its share to the strength of the whole, it follows that to consider alone the isolated efficiency of any particular part is unfair. Thus, while the shell plating affords enormous longitudinal strength to the vessel, it depends upon the assistance of the transverse framing, as well as upon the keelsons, stringers, and decks, in being held to its work, and developing its fullest efficiency. Some parts of the outside plating develop more strength than others. This is discussed in *Steel Ships*, chapter v., on "Stress and Strength." Thus, it is usual to find in all seagoing vessels that the plating is of increased thickness on the topsides, particularly in the sheer strake, and possibly in the strake beneath. In some cases, especially in large long vessels, the sheer strake may even be doubled. As the sheer strake is usually and preferably an outside strake, such a doubling would generally be placed on the inside of the sheer strake. Increased thickness of shell plating is often found to be necessary in one or more strakes of the bilge plating, which is the lower extremity of the ship girder, just as the sheer strake forms the upper. As the longitudinal stresses are greatest over the middle length of the vessel, and are gradually reduced towards the ends, a reduction in structural strength is permissible. We therefore find that all classification societies allow for this in their rules. The midship thickness is usually continued over the half length amidships, reduction gradually taking place towards the ends. However, when we come to the keel and stern frame, the local requirements demand that thick plating be adopted. In the case of the keel, this is easily understood when it is remembered that there is the possibility of the vessel frequently lying aground, with consequently severe wear and tear. The necessity for thick plating, where flat plate keels are adopted, is obvious. When a keel of the bar type is fitted, the strakes of shell plating which are attached to it on either side (the garboard strakes) again require to be of exceptional thickness. This is necessary in order to obtain plating somewhat compatible with the thickness of the bar keel and its large, widely-spaced rivets. The absurdity of riveting a thin plate to a thick bar with large rivets widely spaced is evident, if watertightness is to be ensured. As previously pointed out, the lower edge of the garboard strake should be kept about a quarter of an inch from the bottom of the keel, not only to facilitate caulking, and relieve the plating of strain in the event of grounding, but to preserve the caulking and watertightness, which would suffer should such vessels be accustomed to chafe on sandy bars or bottoms. The shell plating which is connected to the stern frame should be at least of the midship thickness for reasons just given where plates have to be connected to thick bars or forgings. Moreover, the vibration which is suffered in this locality, owing to the action of the propeller when being immersed and emerged in heavy seas, demands that the thicknesses of the material connected bear some consistent relation towards each other. Thick plates are particularly required round the boss. As both boss and oxter plates (shell plating over propeller arch) have to be furnaced and hammered in order to be brought to their required shape, these plates must be annealed before being fixed in position. By increasing the thickness of the shell plating at the fore end for about 20 or 30 ft. from the stem, ships which have frequently to break their way through ice may be considerably strengthened. Such thickening of shell plating will also enable the vessel to more effectively resist panting action, and minimise the tendency in lightly-built vessels to fall hollow between the frames, owing to the pressure upon the bows when driving ahead. This also makes a more satisfactory connection to the stem bar. Where this increased thickness is adopted only on account of the possibility of ice being encountered, such increase of thickness need only extend between light and load lines. Two or three shell strakes on either side of the keel should of necessity be at least equal to the thickness of such strakes amidships for say $\frac{1}{8}$th of the vessel's length from the stem, on account of the severity of the thumping or pounding which especially bluff ships experience when driving ahead and plunging into head seas. Valuable strength is further afforded in this region by carrying all intercostals between the floors as far forward as possible, or even by introducing additional intercostals; and also by doubling the frames round the lower girth of the shell in this locality, in which case two flanges instead of one support the shell plating.

A most important consideration in the arranging of shell plating should be to ensure a good disposition of butts. No butts in adjacent strakes should come nearer to each other than two frame spaces, and in alternate strakes than one frame space. Similarly, butts of deck stringers, side stringers, tank margin plates, centre through-plates, keelsons of bar keels, or butts of side bar keels, should be kept clear.

Fig. 130 illustrates an expansion of the shell of one side of a vessel, and shows the disposition of butts, etc.

Where very short plates are adopted in the outside shell, to carry out such an arrangement would be impossible; hence it is usual to stipulate that no shell plates be less than 7 frame spaces in length, excepting the plates at the extreme ends of ships. Indeed, with the adoption of larger and improved machinery in recent years, shell plates of 10 and more frame

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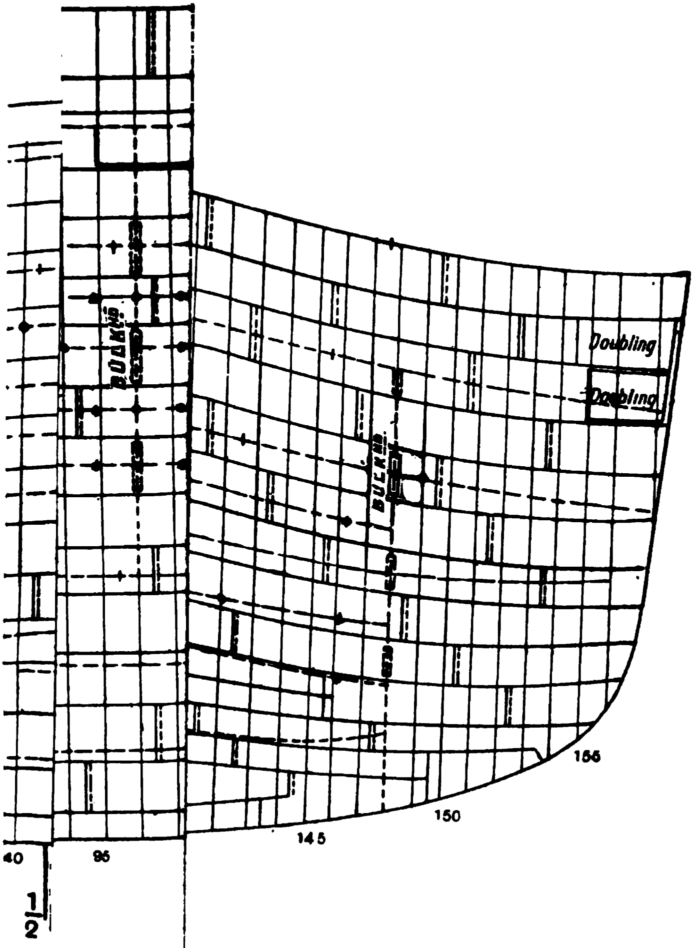


spaces in length are commonly adopted. The nature of butts and seam connections, including the riveting, has already been fully dealt with and illustrated. See "Rivets and Riveting," p. 108.

Packing.—When the strakes of shell plating are arranged alternately, one inside (*i.e.* bearing upon the frames) and one outside (*i.e.* the edges resting upon the edges of the adjacent strakes and forming the seams), as illustrated in figs. 7, 13, etc., it will be seen that something must be done to secure a firm connection between the outside strakes and the frames. This is effected by fitting what is called "packing iron" on all frames in way of all outside strakes of plating. This packing iron must necessarily be of the thickness of the adjacent inside strakes. The riveting through all outside strakes and the frames must therefore pass through this packing iron. Packing iron is necessary, not only in the shell plating, but in decks, tank top, etc., when this arrangement of plating is adopted. When a steel deck is laid with the strakes of plating in and out, as shown in the three steel decks of fig. 13, and also on the tank top of the same fig., the packing iron must of necessity be tapered to suit the shape of the space between the beam or reverse bar and the plate, as the case may be. Sometimes an in and out strake is adopted in the shell plating (see the bilge strake in fig. 13), when taper packing is likewise necessary. All this packing obviously adds greatly to the weight of a vessel; but in recent years it has been largely dispensed with by joggling the edges of what would be the outside strakes of shell plating, decks, tank tops, etc. (see figs. 39, 42 to 47). See page 126 *re* riveting in seams of joggled plating.

By this means, not only is a saving of weight effected, but superior workmanship is assured, for a standing rule ought to be, never to rivet through more than two thicknesses if it can possibly be avoided,—the less the number of thicknesses, the more reliable the riveting.

The strength of butt joints, and the size and spacing of rivets in both seams and butts, has already been dealt with (see page 115). In order to obtain watertightness, and to thoroughly close up the shell plating, the following two points should be noted:—

Where the seam overlap of an outside strake passes over a butt lap in the adjacent strake (see section through plate landing $x\ y$, fig. 131), the plating of the butt under the landing is planed off in a tapered form, as shown in the diagram, so as to allow the outside strake to bear close on the inside strake, without leaving a tapered aperture, which would otherwise exist were this planing operation not adopted. In the event of this not being done, a piece of tapered packing iron would have to be fitted. In lapped butts of outside strakes, it is not practicable to so plane the butt, and thus tapered packing pieces long enough to take at least three pairs of rivets are fitted.

Wherever the shell plating is weakened owing to excessive perforation by rivet holes, or by the cutting of doors or openings of any kind, compensation should be introduced. Thus, in way of all watertight bulkheads, the shell is perforated by a row of closely spaced rivet holes. This weakness is compensated for by the fitting of bulkhead liners in way of the outside strakes (see figs. 125, 126, 130, 69, and 70), or horizontal brackets (see page 160). Bulkhead liners have already been more fully dealt with in

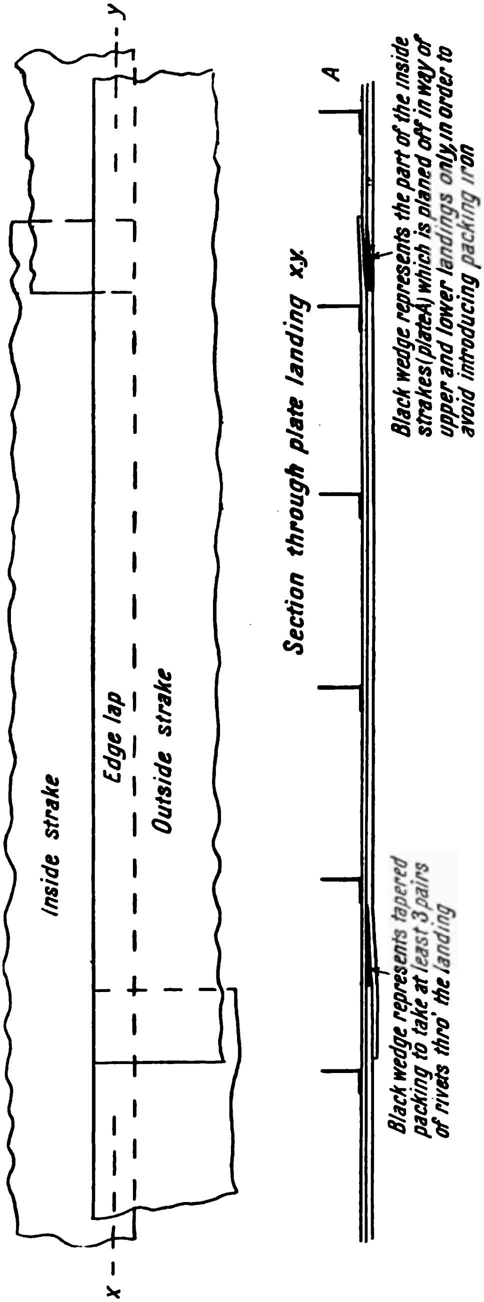


Fig. 131.—Showing the mode of obtaining close work (watertightness) at the butts of both outside and inside strakes of shell plating.

the section on "Bulkheads," as well as in the section on "Oil Steamers." When side lights are cut through a sheer strake, compensation for the weakening of the strake should be introduced, either by increasing the thickness of the plating, or doubling the same, or fitting stout angle bars for at least one frame space in length over all such openings. When openings for doors of any kind are cut through the shell plating, compensation must be made by fitting doubling plates above and below such openings, by framing the opening with stout angle bars, by fitting vertical webs upon each side of the opening, and a fore and aft girder upon the shell above these openings extending a few feet fore and aft on each side of the doorway. Such of these methods should be adopted as are in accordance with the special requirements of the case. In very large vessels and in vessels of extreme length in proportion to the depth, to fit doublings to the sheer strake, and in some cases even to the strake below, is sometimes necessary. When this is done, the butts are usually connected by means of straps, these being necessary for the doublings as well as the other plating.

At the ends of bridges and raised quarter decks or any other erections terminating on the half length amidships, doublings should be fitted to the sheer strake, or, in the case of raised quarter decks connected to bridge houses, the raised quarter deck side plating above the sheer strake should be doubled, the doubling to extend from four or more spaces along the bridge side to a considerable distance abaft of the break, according to size of vessel. Doubling plates should be fitted round hawsepipes (see Doublings, fig. 130).

The bulwark plating at the ends of long poops and forecastles, and at both ends of bridges, should be increased in thickness, so as to somewhat reduce the sudden interruption in longitudinal strength which such erections create. All openings through the bulwarks for waterport doors, or mooring ropes, should have narrow doubling plates fitted round them. As the bulwark is usually constructed of thin plating about $\frac{1}{4}$ in. in thickness, it obviously requires stiffening upon its upper edge. This may be done by fitting special sections of bar iron, which are rolled for this purpose, or bulb angles with half round iron on the outer edge, or even, in some of the cheap tramp types of vessels, a couple of half rounds, one on either side of the top edge of the bulwark plating, may be fitted (see figs. 5, 6, 7, 13, 58 A and B, 61).

The bulwark plating also requires supports of some kind from the deck. These may be specially forged round iron stanchions with a palm on the top, and a fork at half the height, with a palm to take the bulwarks, the lower end of the stanchion having a specially formed foot by means of which a two-rivet connection may be obtained to the deck plating or waterway bar. Other forms of bulwark supports are also made of tee bars and bulb plates (see figs. last referred to).

These bulwark stays should not be spaced more than about 6 ft. apart.

When the butts in the sheer strake are strapped, it is preferable to fit the straps on the outside, covering the full width of the plate. But as this is not only unsightly but often inconvenient, the straps are fitted on the inside, when they should extend from the edge of the strake below to the extreme top of the sheer strake, in which case the gunwale angle bar should be joggled round the straps. When double straps are required to the sheer strake, the outer one must extend over the full width of the plate, while the inside one may extend from the edge of the strake below to the deck stringer plate, and be fitted in a separate piece from the bosom of the gunwale bar to the top of the sheer strake. In this case, a packing piece must be fitted above the top flange of the gunwale bar.

The sheer strake ought to extend sufficiently high so as to get two rows of rivets through the straps above the gunwale bar.

All butts should be carefully planed and fitted close. All butts and seams must be thoroughly caulked.

In preparing a shell plate for its position in the ship, the position of all frame rivet holes (which are punched before the frames are erected), and rivet holes in the seams of adjacent plates, are transferred to the new plate, by means of a template. A template is a framework made of thin wood large enough to cover the area of the plate, with wooden bars across in way of each frame. This is pinned on to the vessel in exactly the same position which the plate itself will occupy, and by means of a whitened cylinder the positions of the rivet holes are transferred to the template. The template is then taken down and laid upon the plate, and by means of what is called a reversing tool the rivet holes are re-transferred to the plate, which is then carried away to be punched, countersunk, and sheared to its exact size. It is then lifted into position in the ship by means of block and tackle, and securely bolted in place. Indeed, the plate must be held by a sufficient number of bolts so as to bring it absolutely close to all surfaces upon which it must fay. In riveting such a plate, especially where the length is great, the riveting is performed from the centre towards the outer edges. By this means, if any slight expansion occurs, due to hammering, and heat from the rivets, it is evenly distributed in all directions, and is therefore practically unnoticeable.

In those parts of the shell where there is considerable change of form, the exact curvature of the plate is ascertained by strips of bar iron (set irons) bent to the correct shape at two or more positions in the length of the plate. The greater number of shell plates can be bent to their required shape in the "rolls," manipulated by skilful platers.

Plates of more irregular shape need to be furnaced and hammered into the required form, and should be annealed.

Stealers.—On examining the shell expansion plan, fig. 130, it will be observed that owing to the greater girth amidships, as compared with the girth towards the ends, notwithstanding the effect of sheer, the strakes of plating get gradually narrower and would eventually become little more than mere strips were they continued to stem and stern posts. This is obviated by introducing what are termed "stealers"—plates of sufficient breadth to take two strakes. Several "stealers" are shown in fig. 130.

Stern Frames and Rudders.

Stern Frames.—The function of the stern frame in a single-screw steamer is to afford support to the rudder and to the tail end shaft and propeller, and to provide an aperture in which the propeller may revolve. The usual form of stern frame for vessels with single screws is shown in fig. 132. Its principal parts are, an after or rudder post, into the gudgeons of which the rudder pintles are fitted, and a fore or propeller post, through the boss of which the tail end shaft passes to carry the propeller. It is obvious, therefore, that with the enormous stress which must be borne by the stern frame, especially in large high-speed vessels, the stern frame must be exceptionally strong in itself, and at the same time that the connection to the main hull of the vessel must be of the most efficient character.

Stern frames may be of cast steel, or forgings made by first forging parts of the stern frame in separate pieces, and then welding the whole together. Naturally, great care must be exercised in the manufacture of a stern frame. The material should be as free as possible from any excess of those elements which are known to produce brittleness. If castings are adopted, they should be free from blow-holes and cavities of any kind; and in the case of forgings, the utmost care is necessary in making the welds uniting the several parts. The classification societies specify the dimensions of a section through the stern frame, based, as a rule, upon the 2nd numeral. Though it is common to preserve the sectional area all round the stern frame, it is perfectly reasonable to reduce such area on that side of the frame supported by the shell plating. When a vessel trims by the stern, it follows that, if she comes into shallow water, the aftermost extremity of the keel, which would be formed by the base of the stern frame, would be the first to touch the bottom. This has frequently happened, with the result that the stern frame has been broken usually at the bottom of the aperture. Sometimes, by fitting a shoe strap, the stern frame may be sufficiently repaired so as to continue to serve its purpose. In other cases, where the damage has been more extensive, the whole stern frame has had to be renewed.

When the whole stern frame is made of a casting or forging in one piece, the enormous difficulty, and labour, and expense, not to mention loss of time incurred in extricating the broken stern frame from the hull, and in ordering and refitting a new stern frame, will be apparent. To obviate this, the arrangement shown in fig. 132, wherein the stern frame is made in two or more pieces connected by means of scarphs as illustrated, is now commonly adopted, especially in large vessels, and as the damage from grounding usually takes place either at the bottom of the aperture or in the after post, it will be seen that this piece can be renewed with comparative ease. A commendable method which may often save a stern frame in the event of grounding, is to lift up the frame at the bottom of the aperture from the propeller post to its aftermost extremity, as shown in figs. 132 and 133. As this may, in some cases, bring the lower part of the stern frame round the

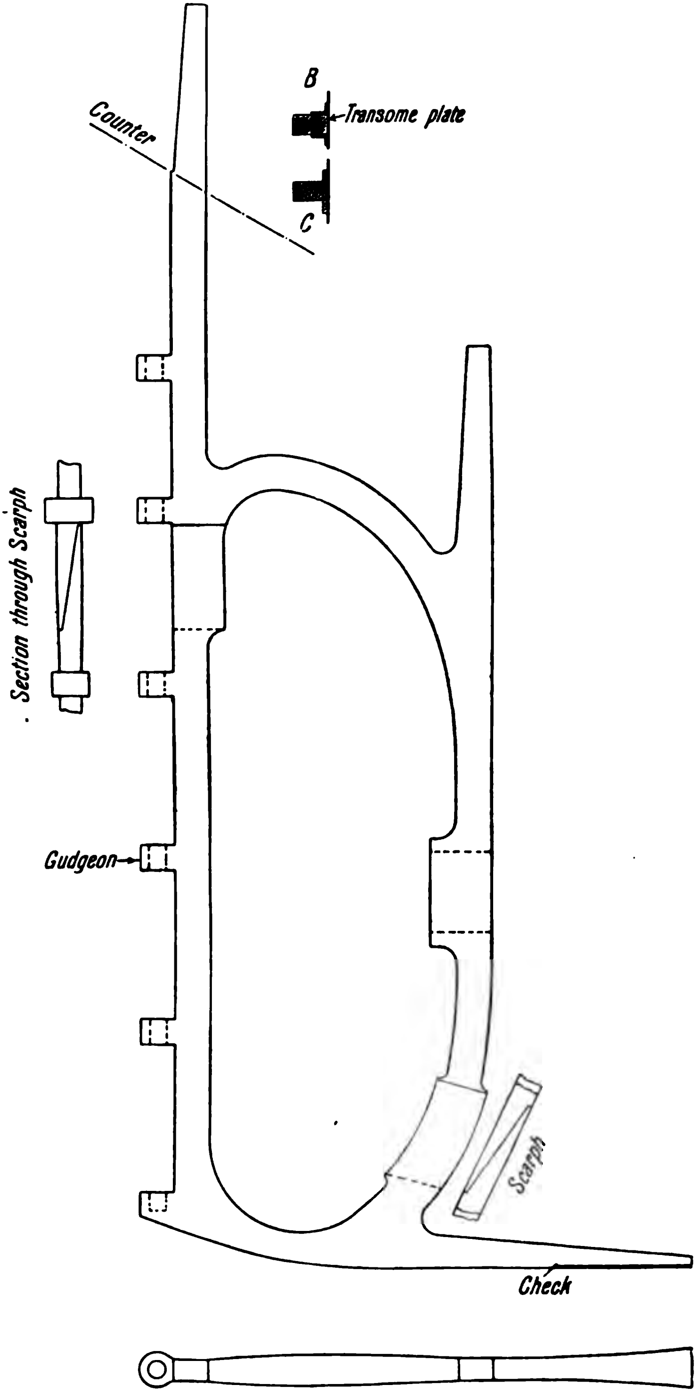


Fig. 132.—Stern Frame for a Single-Screw Steamer. Frame in two parts connected by Scarphs.

bottom of the aperture, in too close proximity to the propeller, the frame is reduced in depth, but increased in breadth at the bottom of the aperture, preserving the sectional area, as shown by the plan of the stern frame, fig. 132.

The connection of the stern frame to the hull, which, as previously stated, should be of the most thorough character, is effected—

1st. By carrying up the after, or rudder post, to a height sufficient to enable a good connection to be made to a thick plate called a transome floor, which extends from side to side of the vessel above the counter on the fore side of the post (see fig. 132, B and C). This transome plate should be at least one and a half times the depth of an ordinary midship floor.

2nd. In large vessels, and in all single-screw vessels of high speed, the fore or propeller post should extend to a height sufficient to enable a good connection to be made to another deep transome or floor plate.

The rudder and propeller posts are connected to their respective transome plates, either by means of large stout angles (see fig. 132, B), or by having a projecting flange upon the post itself, through which the rivet holes are drilled for the connection to the transome plate (see C).

3rd. The lower part of the stern frame, which projects forward of the propeller post, should be of sufficient length to enable a good connection to be made to the keel. In screw steamers, shipbuilders usually make this projection at least three frame spaces. Lloyd's require that the projection be at least 2½ frame spaces before the propeller post in steamers, and 1½ in sailing vessels and paddle steamers. When the keel is of the bar type, the stern frame is connected to the keel by a scarph, as shown in fig. 85, which is in every way similar to the scarphs uniting the several lengths of the bar keel. When the keel is of the side bar type, the scarph is formed as shown in fig. 86. When the keel is of the flat plate type, the projection forward of the propeller post is usually formed as shown in fig. 132. It will be seen that it tapers in respect to its depth; and forward of the check on the bottom of the projection, where the keel plate terminates, it is hollowed out, and conforms to the shape of the bottom of the vessel. The keel plate is thus riveted to the stern frame by independent rivets for each side.

4th. The stern frame is finally attached to the hull by means of the shell plating, which is riveted to it by at least two rows of rivets arranged in zigzag fashion. These rivets should be spaced not more than five diameters apart, and should be about a quarter of an inch larger in diameter than would be required according to the thickness of the plates, which ought to be, at least, as thick as the garboard strakes. They need not exceed 1¼ in. in diameter, as it is practically impossible to get efficient hand riveting with larger rivets.

Although the shell plating is reduced in thickness from the half-middle length to the ends, the plates which take the stern frame should be at least equal to the midship thickness, or garboard strake thickness, and especially so round the boss of the propeller post, for the absurdity of connecting a huge, heavy stern frame, weighing twenty or more tons, to comparatively thin plating by large rivets must be apparent.

The rudder is supported and secured to the propeller post of the stern frame, though with every facility to swing freely, by means of pintles, which fit into a number of gudgeons on the rudder post of the stern frame. Detailed sketches of these gudgeons are shown in figs. 133–138. The spacing of these gudgeons upon the stern post should not exceed 5 ft. 6 in. Whether the stern frame is of cast steel or forged iron, the gudgeons should form an integral part of the post. The weight of the rudder is usually borne upon the bottom gudgeon, though, in some cases, the weight is taken upon one of the decks, through which the rudder stock passes, by means of a collar forged on to the post which rests upon a suitable casting firmly secured to the deck and well supported. The "Ocean Steamship Co.," of Liverpool, have shown in their latest single-screw steamers that the huge, heavy, costly, and cumbersome stern frame can be dispensed with altogether by the ingenious and well-thought-out arrangement illustrated in fig. 56.

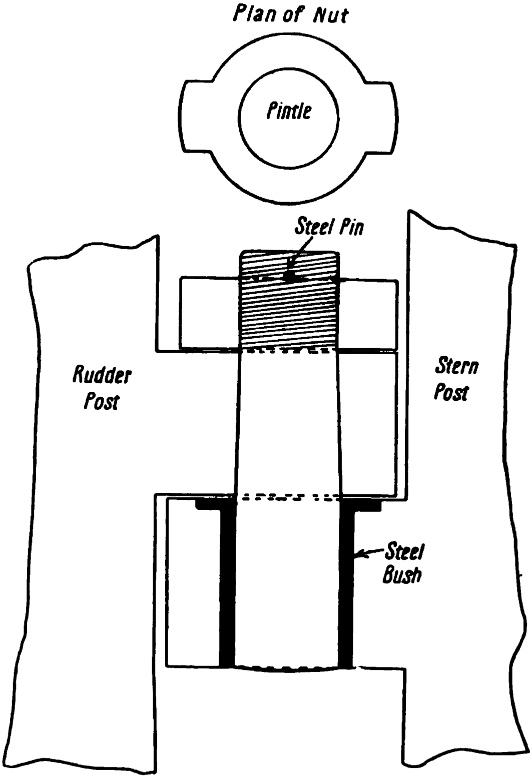


FIG. 133.—Fitted Pintle.

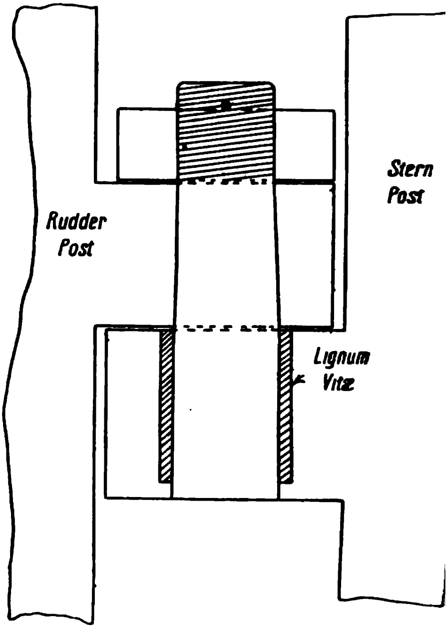


FIG. 134.—Fitted Pintle.

This system of stern arrangement has already been dealt with on p. 85. Notwithstanding the radical change which has taken place in this stern arrangement, and the suspicion with which such innovations are often viewed, these vessels have performed with complete success the round journey to China and back, carrying a deadweight of over 8000 tons, while the increased facility for steering has proved a decided advantage. Cutting away and dispensing with the fin of plating extending from below the boss to some distance forward, has not only lessened the resistance to steering, but reduced the severity of the straining and vibration which is usually experienced in this neighbourhood.

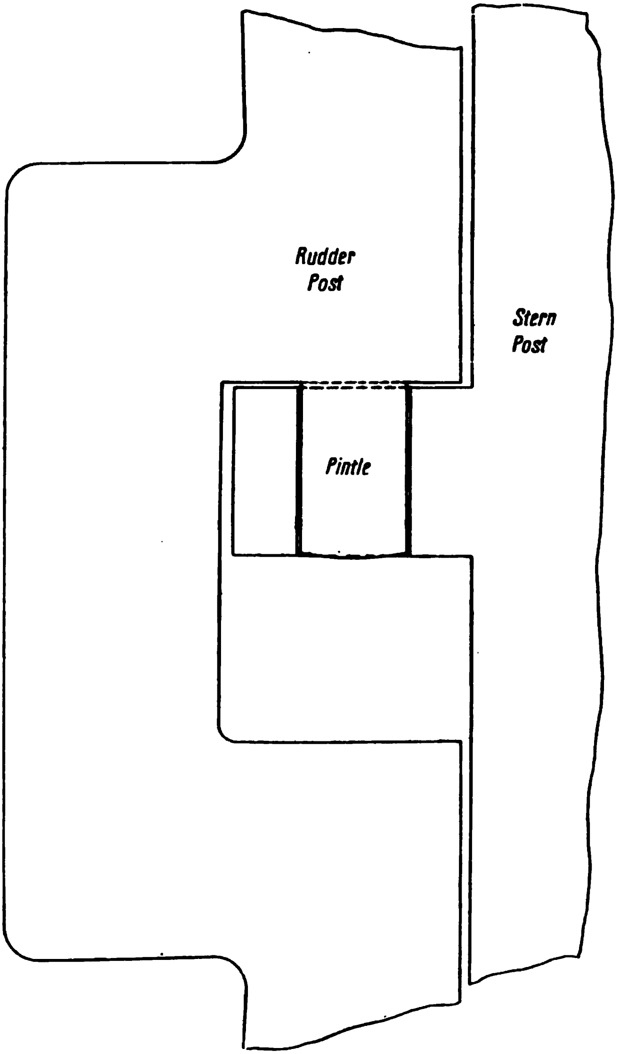


FIG. 185.—Pintlets forged on Rudder Post (unbushed).

The rudder, which is of special design (see fig. 56), is of such a shape as to offer the least resistance to propulsion compatible with the principle of its design.

Stern Arrangement for Twin Screws.—In all vessels with twin screws, there comes a place towards the stern where the propeller shafts would emerge from the hull, if the usual form of hull were in no way modified. The length, from the point where the shafts so emerge to the propellers, will

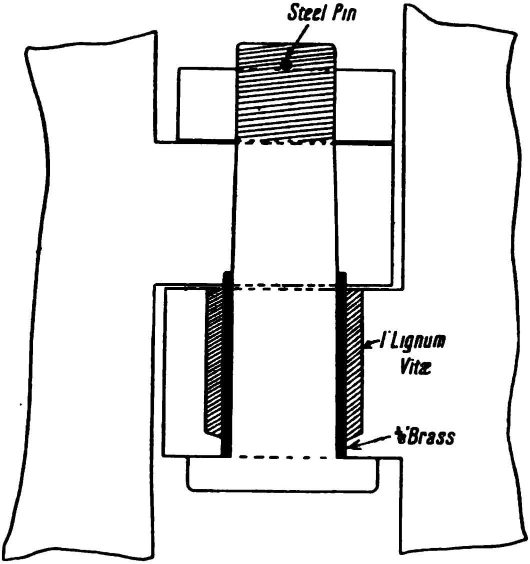


FIG. 136.—Locking Pintle.

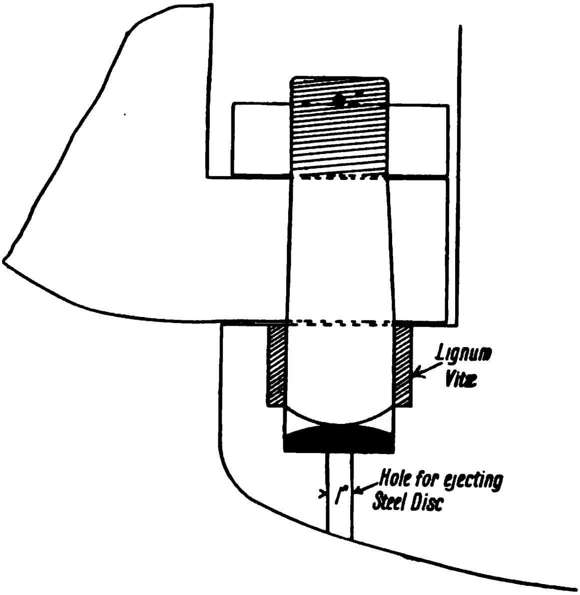


FIG. 137.—Bottom Pintle.

vary according to the size and fineness of the lines of the vessels; therefore in all such cases the shafts require support at their aftermost lengths. The old-fashioned method of affording this support was by bossing out a few frames round the shaft in the neighbourhood where it would emerge through the shell plating, and at the aftermost extremity supporting the shafts by means of struts such as shown in figs. 139, 140, 141, and 142. These struts may be either forgings or castings.

Fig. 139 illustrates a stern frame somewhat after the pattern required for a single screw. The aperture in this case is necessary, because the propellers overlap to some extent, and, as the diagram shows, the stern frame is manipulated to receive the palms at the upper and lower extremities of the struts.

In fig. 140 the propellers are amply clear, and no aperture is necessary.

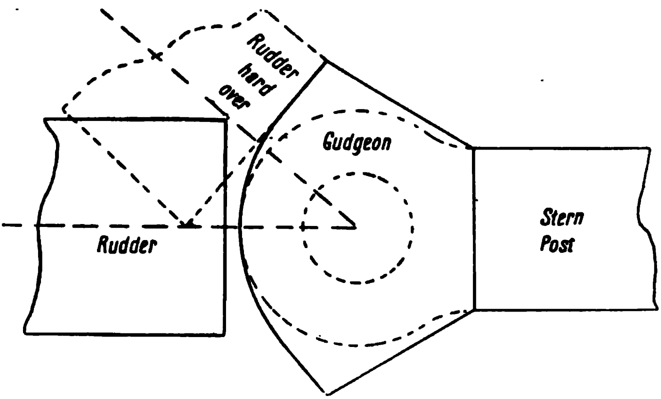
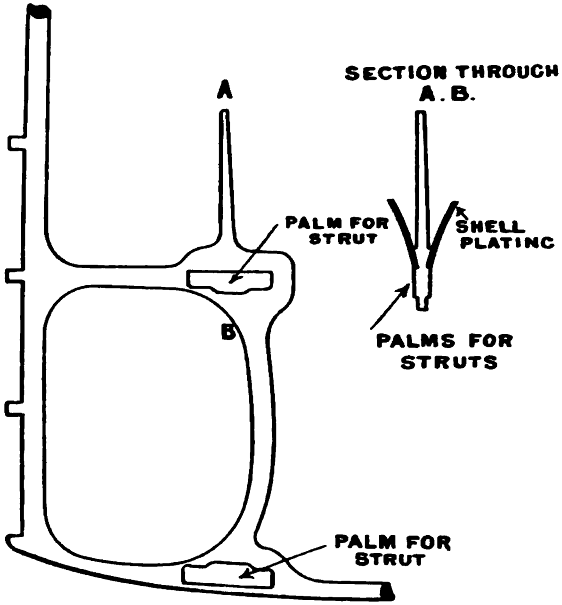


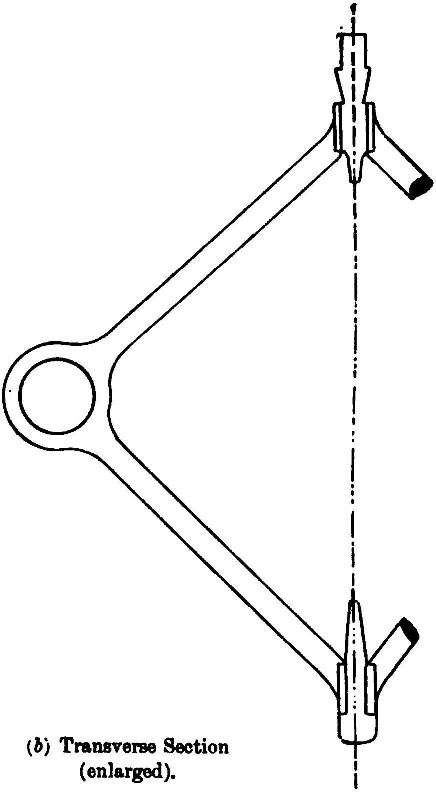
FIG. 138.—Rudder Stopper.

In this case, the upper palms of the struts are riveted on to the shell plating, which is doubled, and supported by a thick bulkhead with large, thick, double angles through which the rivets of the upper palms pass (see fig. 141). The lower palms are riveted through the keel bar, or through the keel part of the stern post. In fig. 142 the struts pass through the shell plating, and the upper palms are secured to a fore and aft and to a transverse plate, as shown; but by far the best method of supporting twin-screw shafts at their aftermost extremities is to carry the framing round the shaft right aft to the propellers, and to work the shell plating round this. With a sufficient number of transverse ties and bulkheads, this arrangement is exceedingly strong, and much less liable to suffer damage than the strut arrangements previously described.

Special support is provided for the extreme ends of the tail shaft by means of what are commonly known as the spectacles. This is usually a steel casting in one piece, firmly bolted through the fore post of the stern frame, and securely riveted to the bossed plating of the shell. The notes



(*a*) Elevation.



(*b*) Transverse Section (enlarged).

FIG. 139.—Connection of Struts with Stern Frame in Twin-Screw Steamers: *a*, Elevation; *b*, Transverse Section.

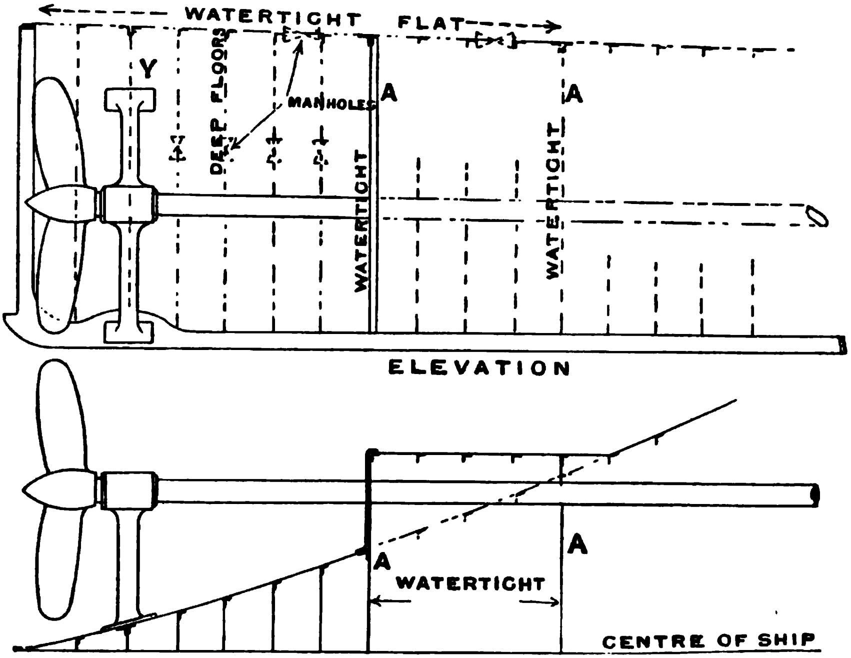


Fig. 140.—Mode of Strengthening Ship at the after end and attaching Struts to Shell Plating.

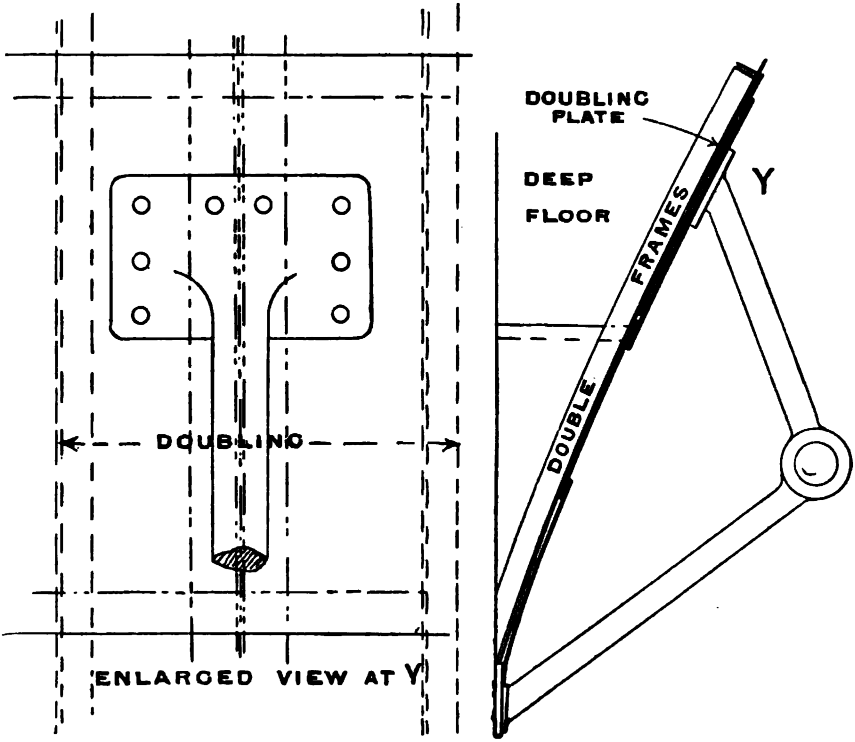
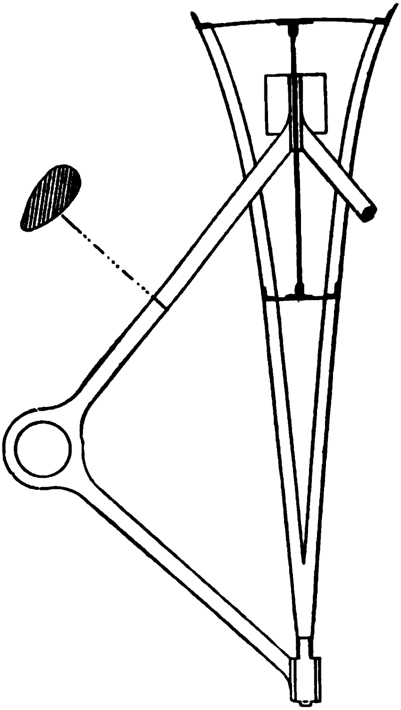


Fig. 141.—Mode of Strengthening Ship at the after end and attaching Struts to Shell Plating.



Sectional Elevation of Struts.

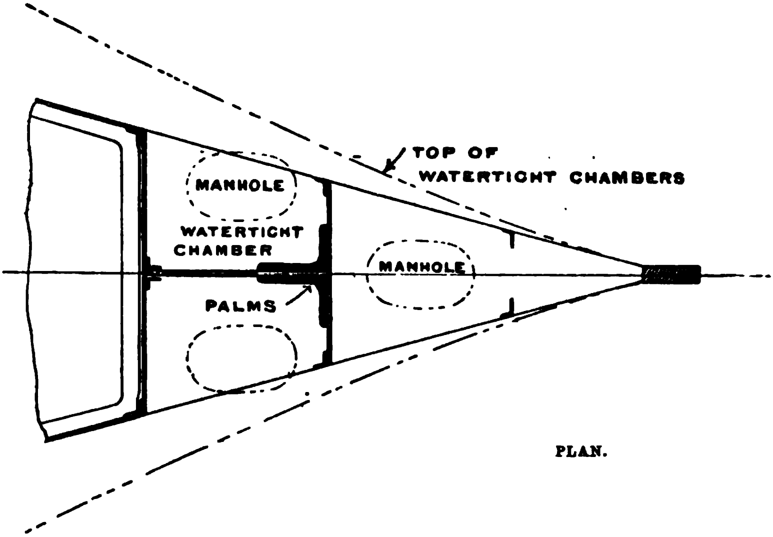


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Fig. 142.—Struts carried through Shell Plating into Watertight Chamber.

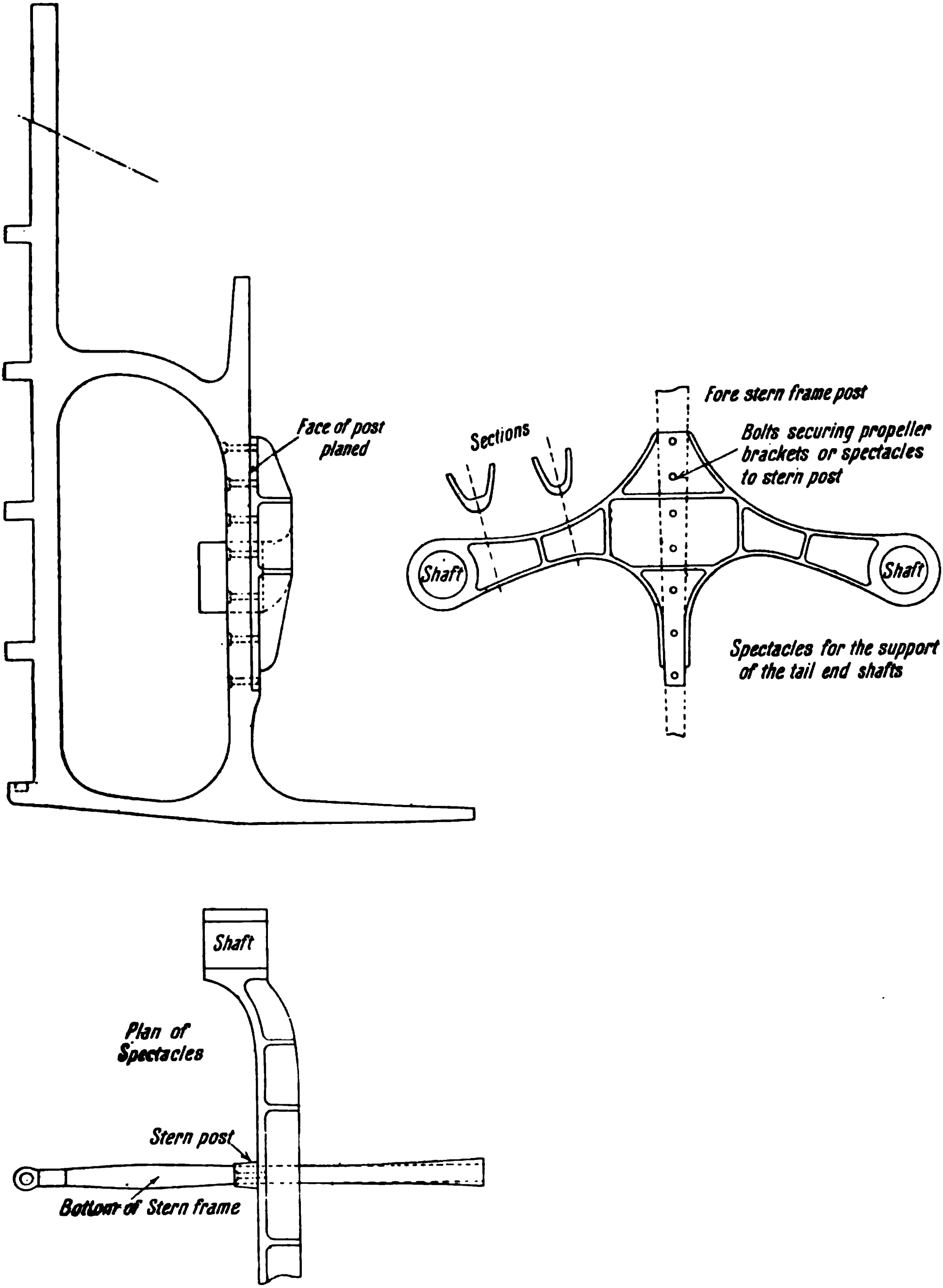
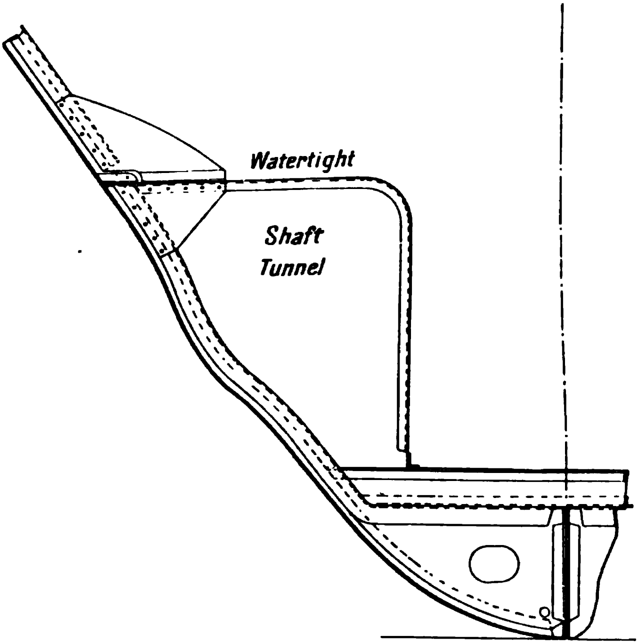
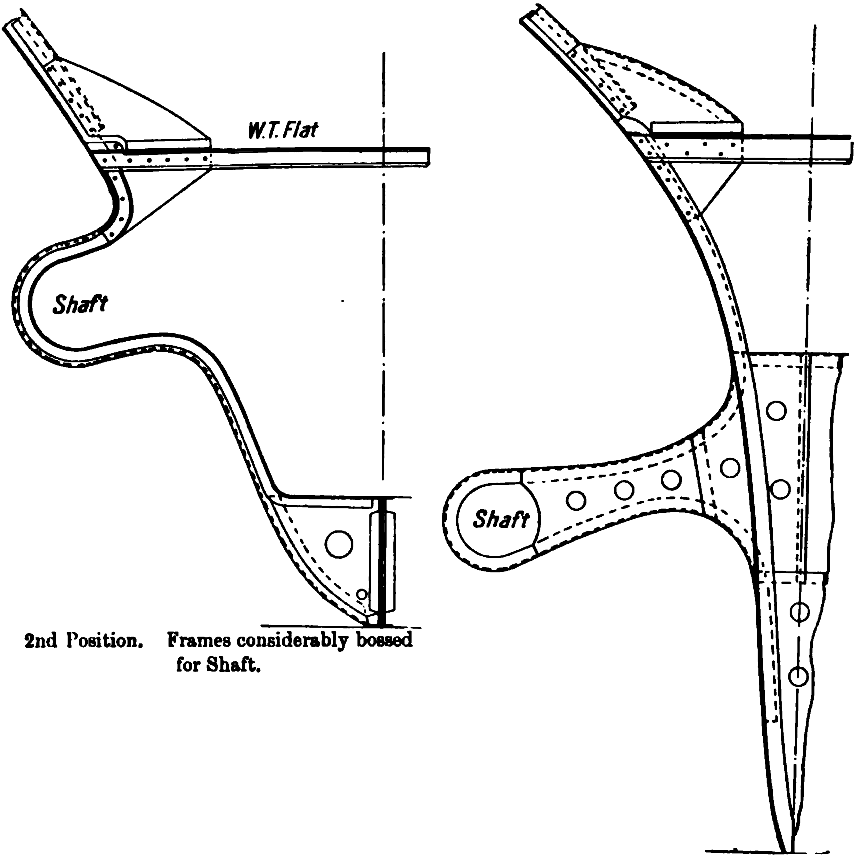


FIG. 143.—Stern Frame and Spectacles for Twin-Screw Steamer.



1st Position. Frames slightly bossed for shaft.



2nd Position. Frames considerably bossed for Shaft.

3rd Position. Frames carried down as usual, and separate framing bossed for shaft, and connected to the main framing as shown.

Fig. 144.—Showing Bossing of Frames in Twin-Screw Steamer at 3 intervals.

upon the diagrams are sufficient to give a general idea of this mode of construction (figs. 143 and 144).

Rudders.

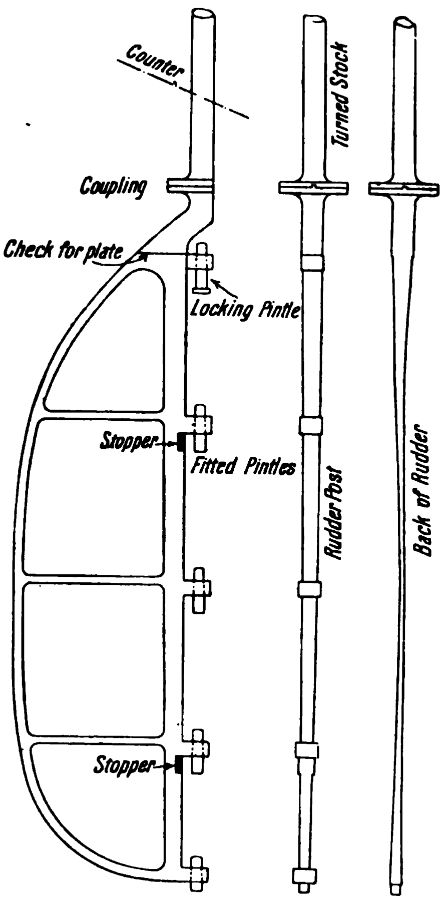


Fig. 145.—Frame Rudder.

Rudders for merchant steamers may be divided into two kinds, the ordinary frame rudder and the plate rudder. The frame rudder is usually a forging, and in construction as illustrated in fig. 145. The rudder framework is plated on each side, and the space between the two plates is filled in with wood. The number of stays, stiffening the rudder in a fore and aft direction, varies with the size of the rudder, but one is usually placed opposite each gudgeon. Until within recent years, the rudder frame and stock was generally all one forging, but the awkwardness and inconvenience of unshipping a large rudder of this kind led to the adoption of the method illustrated in fig. 145, in which the upper rudder stock is an entirely separate forging, being connected to the main rudder itself by a bolted coupling, as shown, which may be either vertical or horizontal.

The plate rudder is somewhat different. It consists of a main post usually coupled to the stock, and instead of a plated frame, a very thick plate formed to the required shape of the rudder is notched into the main rudder post, and supported at intervals with arms alternately on each side, which may be either forged into the post or shrunk on, as shown in fig. 146. The rivets connecting the side plates to the rudder frames in the case of frame rudders, and the thick plate to the arms in plate rudders, are usually spaced about five diameters apart. In the case of classed vessels, the size of rivets is specified by the registration society.

Stern Frame Gudgeons and Rudder Pintles.—As before stated, the gudgeons are forged on to a forged stern frame, or form part of the casting when of cast steel. The pintles on the rudder may either form part of the forging of the rudder frame, as shown in fig. |135, or, as is much more commendable, the pintles are fitted separately, and held in position by a nut with a check pin, which bears upon the head of the nut (see figs. 133, 134, 136, 137). Fitted pintles are also illustrated in the rudder frames (figs. 145 and 146).

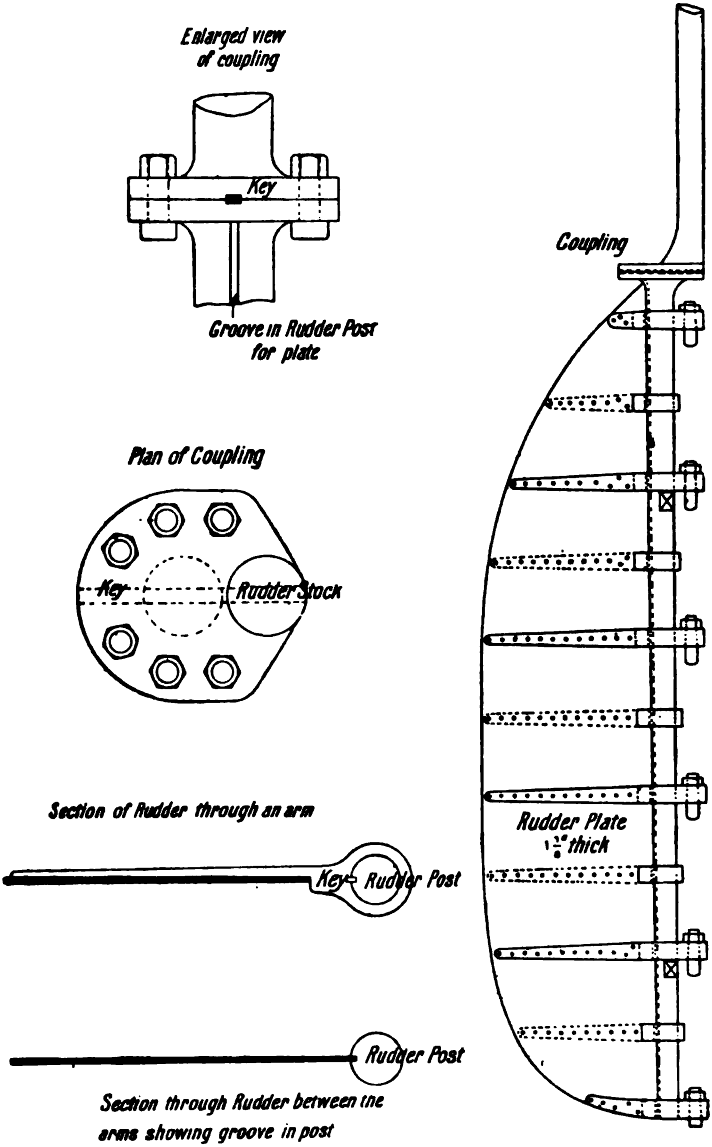


FIG. 146.—Plate Rudder, showing Arms shrunk on and keyed.

A considerable amount of wear and tear must eventually take place owing to the incessant wearing action incurred by the rudder's movements when the vessel is under way. Numerous devices are adopted to prevent, or, at any rate, to make the wear and tear of such a nature that it can be repaired with a minimum of inconvenience and expense. When the pintles are forged to the rudder and fit into the gudgeons, as in fig. 149, with no other bearing surfaces than the bare metal of which they are made, repair is not always an easy matter. If the wear has not proceeded too far, the slackness of the pintle in its gudgeon may be taken up by fitting a brass bush, either to the pintle, or inside the gudgeon, whichever is worn most. But when the pintles are portable, and the gudgeons are bushed with lignum vitæ or steel or gun-metal, and the pintles bushed with brass after the manner illustrated in figs. 136, 137, 133, and 134, the wear and tear being confined to the bushes, these parts are renewed at comparatively little trouble and expense. When the weight of the rudder is transmitted through the bottom pintle to the stern frame, the wear and tear is naturally more rapid at this part. A good plan is to fit a round-topped steel disc, which is easily extracted and renewed, if a hole about one inch in diameter be drilled through the bottom gudgeon, as shown in fig. 137, or, instead of the steel disc, a piece of lignum vitæ with the grain up is fitted into the bottom of this gudgeon hole, forming a good bearing for the bottom pintle.

To prevent the possibility of the rudder lifting by a heavy blow from a sea, it is common to fit one of the upper pintles with a forged head upon its lower end. This is called a locking pintle (see fig. 136).

As rudders are not usually allowed to turn more than an angle of 40° or 45° on either side, it is essential to have what are called stoppers, usually upon the gudgeons, and, if necessary, upon the rudder as well. Fig. 138 illustrates a rudder stopper, and the manner in which the gudgeon is formed so as to prevent the rudder turning beyond the desired angle. Two stoppers are usually fitted to each rudder, one upon an upper and one upon a lower gudgeon (see figs. 145 and 146). As the rudder stock tapers towards its lower extremity, a projection is sometimes made upon the rudder for the lower stopper, in order to get sufficient bearing surface for the check at the maximum angle. (See fig. 145.)

Tests for Steel Castings.

The tests for steel castings in the hulls of ships are generally as follows:—Cast steel stern frames, rudders, steering quadrants, and tillers must be subjected to percussive, hammering, and mechanical tests, in the presence of one of the society's surveyors, so as to ensure the material being of ductile quality. A tensile test is to be made on a piece taken from each casting, and the extension on a length of 8 in. is not to be less than 8 per cent., and the tensile strength not less than 28 tons, nor more than about 35 tons, per square inch. A cold bending test must also be made corresponding to each tensile test, and the sample must bend cold before fracture through an angle of at least 90°. Large stern frames cast in one piece must be allowed to fall on a hard flat ground (excavations being made to take the boss part and other projections) after being raised through an angle of 45°. Stern frames cast in more than one piece, and rudders, must be dropped from a height of from 7 to 10 ft., according to the design, shape, and weight of the casting. The casting in such case must subsequently be slung up, and well hammered with a sledge hammer, not less in weight than 7 lbs., to satisfy the surveyors that the castings are sound and without flaws, either existing originally, or developed as the result of the application of the preceding percussive tests.

Miscellaneous Details.

Continuity of Strength.—Nothing is of more vital importance in ship construction than that the continuity of all the principal structural parts be rigidly maintained. Wherever interruption takes place in the mode of construction in any part, which in itself would produce weakness, compensation must be introduced in such a manner that the continuity of strength will be assured. Thus:—

(1) Whenever a deck has a break in any part of its length, the one part being at a higher level than the other, as in the case of a main and raised quarter deck, the strength of the two parts must be united by overlapping the decks, side stringers, and increasing the thickness of the shell plating in way of the break (see fig. 12).

(2) Sometimes the bottom of a ship is built with ordinary floors in one part of the length, and with cellular double bottom throughout the remainder. Wherever this occurs, the strength of the one must be scarphed into the strength of the other by carrying the keelsons on the ordinary floors into the tank for three or more frame spaces.

(3) Where decks or stringers are unduly weakened by openings through the deck, or reduction in effective breadth, the strength must be maintained by increasing the thickness of the remaining plating or by doublings. The same applies to the outside shell plating (figs. 129 and 130).

(4) If stringers or keelsons are cut in way of bulkheads, their strength must be continued by connecting them to the bulkheads with large bracket plates.

(5) Where the transverse framing suffers interruption in its continuity from keel to gunwale, as at the margin plate of double bottoms, and sometimes where it passes through a watertight flat, the continuity of strength must be maintained by fitting large bracket plates (tank knees) (figs. 12 and 64).

Engine and Boiler Space.—The structural strength of the engine and boiler space needs special consideration. The great interruption which takes place in transverse strength owing to the cutting of so many deck beams in order to make the light and air openings through the decks, and the omission of so many hold beams, necessitates efficient compensation.

We have already seen how the deck ends are bound together and carried on the thick fore and aft coaming plates, but, in addition to this, a good number of extra strong continuous beams should be fitted wherever practicable in way of all the decks; and by converting these, where possible, into semi-box beams by uniting and covering them with plating, valuable strength is introduced (see figs. 12, 13, 14, and 35).

Especially in high-speed vessels is there the tendency to excessive vibration where this part is in any measure weak. To ensure against this, and to make the vessel as rigid as possible, not only are the reverse bars doubled on the floor plates under the engines and boilers, but the double bars are sometimes carried to the upper deck. To compensate for the loss of through-beams, it is also found to be very beneficial to the vessel to introduce several web frames into these spaces, and to thoroughly connect the stringers to them, as illustrated in fig. 13. In vessels having double bottoms, one or more additional intercostal girders should be introduced, at any rate under the engines, while the tank top plating in these spaces should be increased in thickness. On account of the rapid corrosion which shipowners find to take place, especially under boilers, the tank top plating is sometimes entirely dispensed with, and a form of construction similar to that shown upon fig. 147 is often adopted.

It will be noticed that the tank margin plate is carried continuously all fore and aft, while the keelsons shown must be scarphed into the double bottom. In some cases the double-bottom form of construction is carried continuously all fore and aft, with the exception that large openings are left through the tank top plating between the floors and the fore and aft girders, which are so large as to permit of easy and ready access at all times.

Masts and Derricks.—Masts are nowadays most frequently made of steel. In sailing vessels, where they are very long and of large diameter, there may be three plates in the round, with angle or tee bar stiffeners throughout their length.

In steamers, however, where the masts are usually short, carrying very little sail, two plates in the round are usually adopted, with or without stiffeners as the case may require. All masts should be doubled in way of the wedging at the upper deck for a length of about 4 ft. above and below the deck. The butts of the plates should be well clear of each other, and connected by either straps or overlaps. The edge riveting is usually single in steamers, while the butts above the upper deck should be treble riveted, and below, double riveted. Masts are secured at the deck and heel by angle collars which may be riveted or wedged to the mast, and also by means of a good disposition of shrouds well connected to the sheer strake (see figs. 12 and 14).

In small vessels, or in vessels of moderate beam, the derricks for the loading and discharging of cargo are usually pivoted to the mast, as shown in figs. 48 and 57. Derricks always swing most easily when the masts are perfectly vertical, having therefore no rake. In large vessels of great beam,

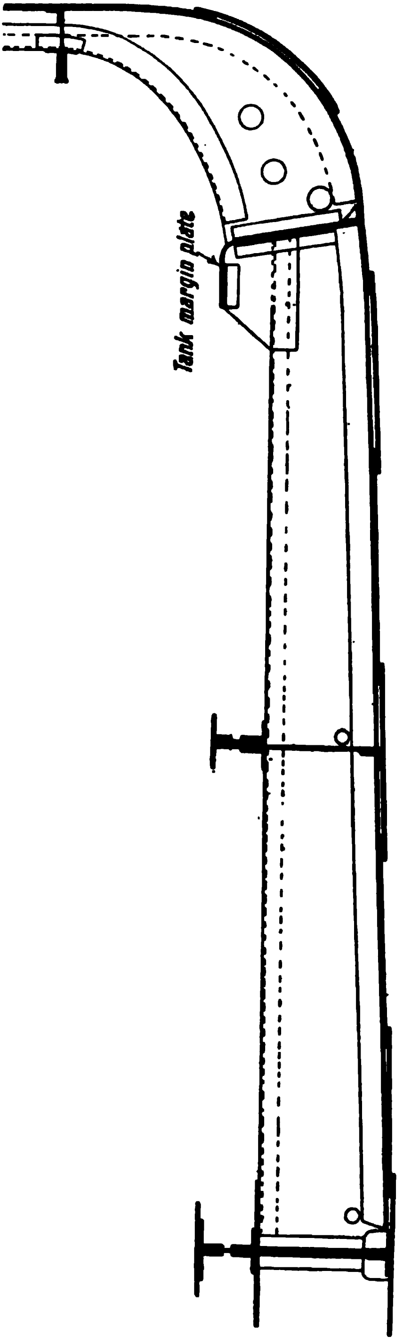


FIG. 147.—Cellular Double Bottom discontinued under boilers, and Ordinary Floors introduced.

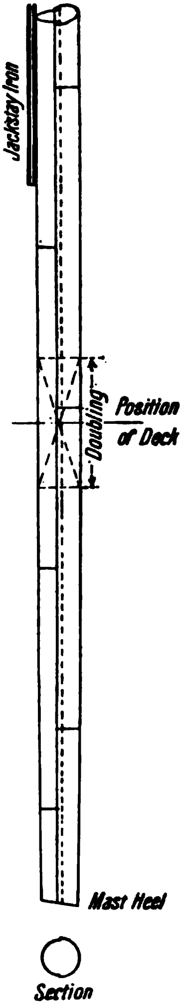


FIG. 148.—Steel Mast.

the length of derrick, to enable cargo to be swung clear of the vessel's side, would be so extraordinary, that some means have become necessary to curtail their length within reasonable dimensions. This can be done by fitting special derrick posts to the deck, or by making the main ventilators of extra strength and height to serve as supports upon which the derricks may swing (fig. 151).

But by far the best system of arranging the derricks is as shown in figs. 152 and 153. In this arrangement, special tables are fitted to the mast at a height of about 7 ft. from the deck, and supported by stanchions and brackets as shown. The length of these tables transversely from the mast will depend upon the beam of the ship and the minimum length of derrick required. The advantage of relieving the derrick tables of as much thrust from the derricks as possible, by fitting a post from the deck to the derrick heel as shown, is obvious. Fig. 152 shows an arrangement of mast tops so designed that the pivoting point of the derrick topping lift is vertically above the derrick heel, thereby greatly facilitating the easy swinging of the derrick. The derricks as illustrated in figs. 152 and 153 are such as are fitted to the steamer in fig. 53, which is designed for the rapid loading and discharging of cargo. Three derricks, it will be seen, are fitted to the fore and to the after side of each mast. Fig. 152 shows the middle derrick resting upon a small table just above the larger tables, while fig. 153, B, shows a method of securing these derricks in a vertical position to the masts when the ship is at sea. The other derricks are laid in a fore and aft direction, and may rest either upon a poop, bridge, or forecastle end, or upon special stanchions. The function of the middle derrick is to lift heavy cargo out of the hold, while that of the two side derricks is for lighter cargo only.

Fig. 154 illustrates the cast iron socket (fixed to the deck) of an extra strong derrick for lifting exceptionally heavy weights.

Fig. 149 illustrates a telescopic mast, and fig. 150 a patent hinged topmast (Sidgwick's). Arrangements for lowering the topmasts are necessary in vessels which are required to pass under bridges, and which use such waterways as the Manchester Canal.

Panting.—The principal methods adopted to resist panting may be enumerated as follows:—

(1) A closer spacing of frames.

(2) Double frames.

(3) An extra tier or tiers of beams with stringer plates on their ends well connected to the shell, or additional double angle, tee bar, or intercostal panting stringer may be introduced.

In addition to the breasthook which receives the stringers at the stem, it is often desirable, especially where there is considerable distance between the first frame and the stem bar, or where considerable rake is given to the stem, to introduce additional breasthooks between the stringers.

(4) Floors of extra depth.

(5) An increase in the thickness of shell plating, especially under the fore foot, where excessive thumping is experienced.

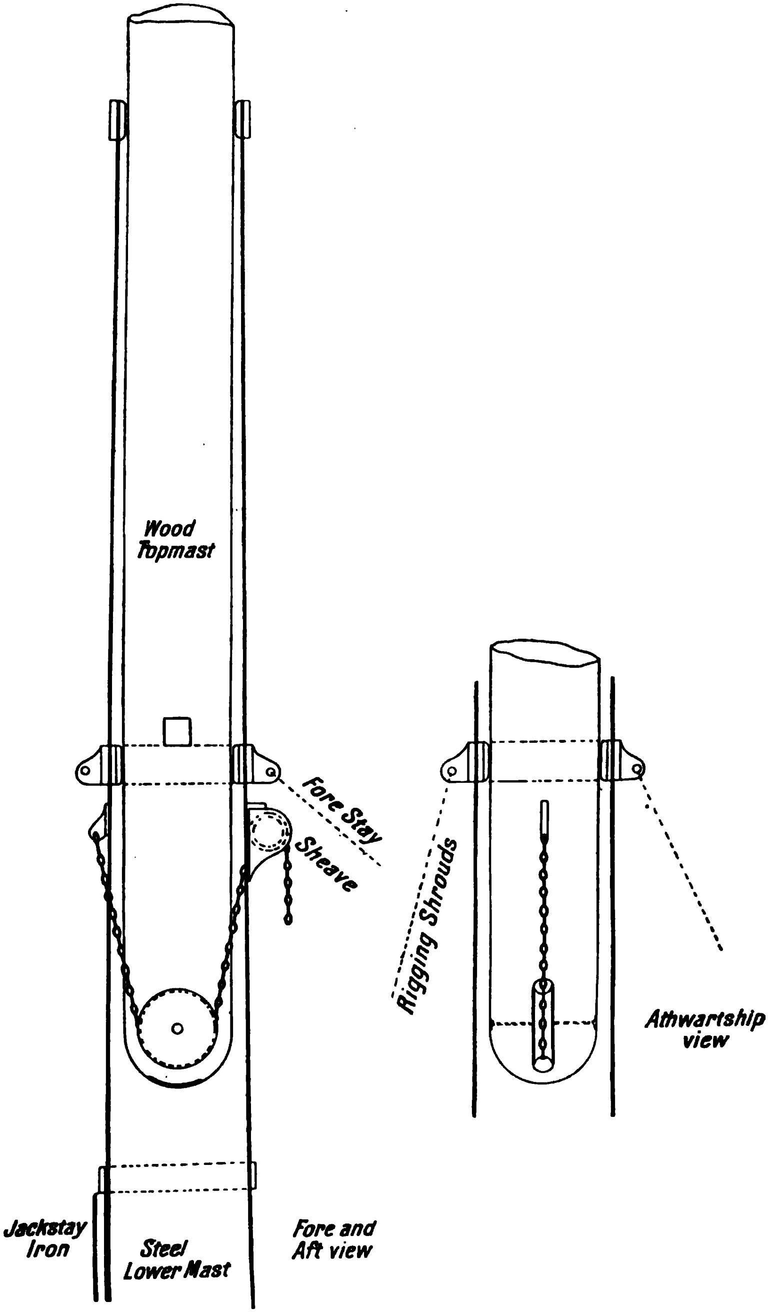


FIG. 149.—Telescopic Mast. Showing arrangement for lowering Top Mast.

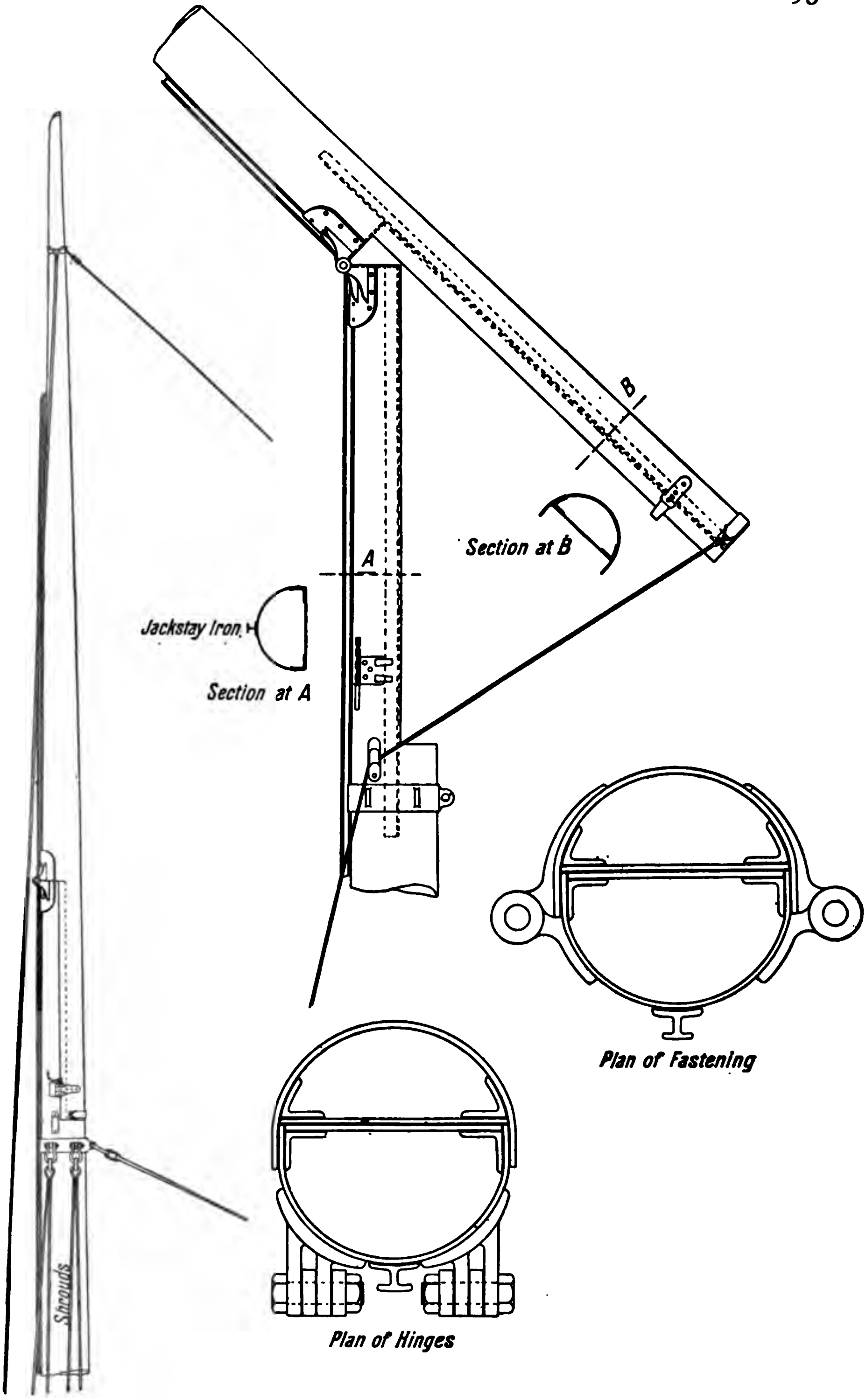


Fig. 150.—Hinged Top Mast. (Sidgwick's patent.)

(6) The middle-line keelson should be fitted intercostally as far forward as practicable.

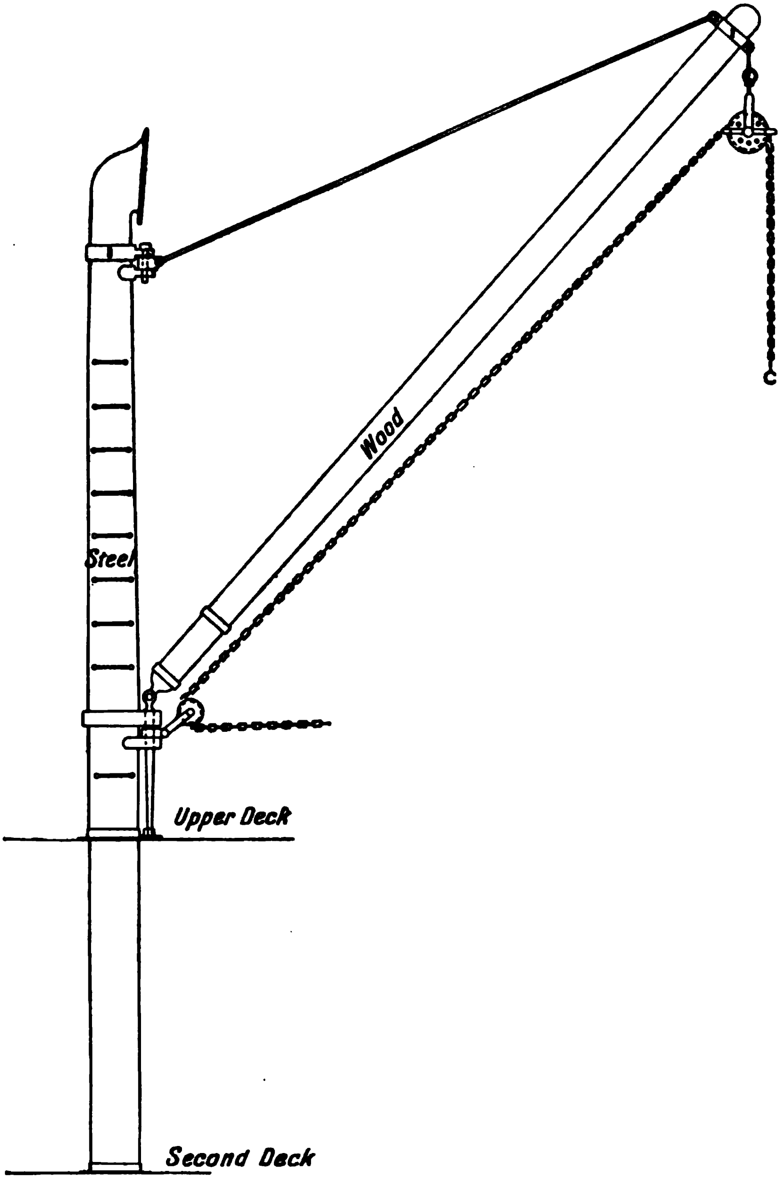
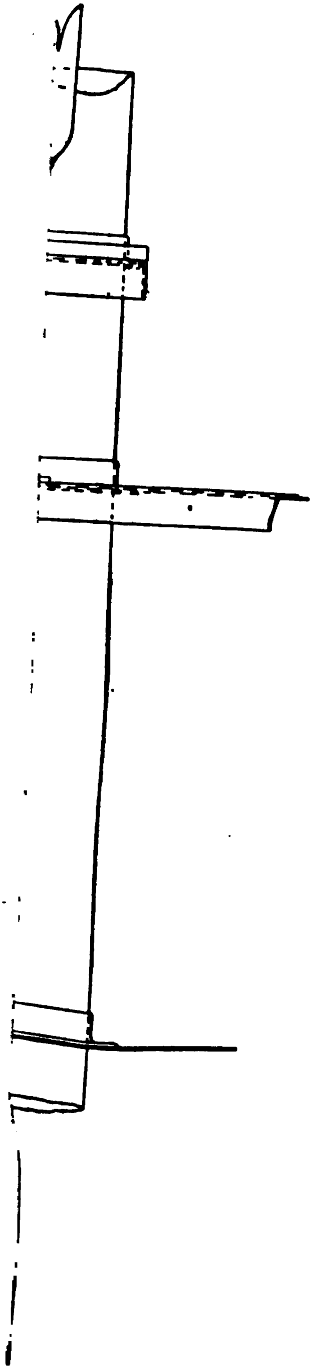
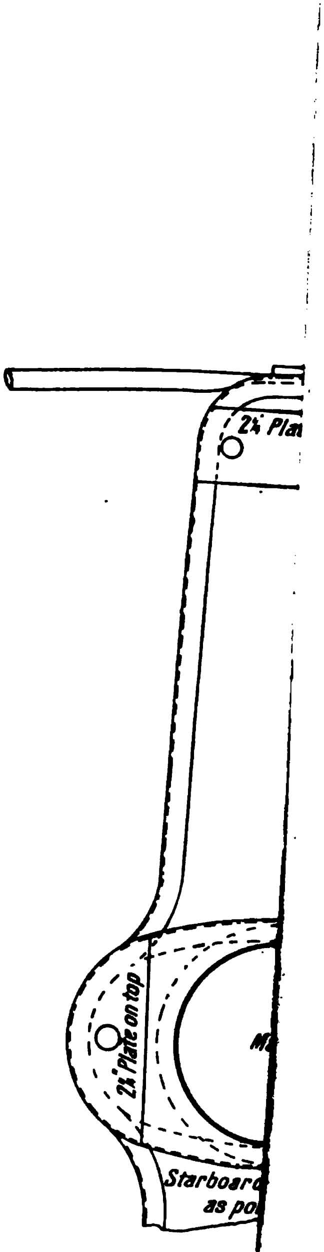


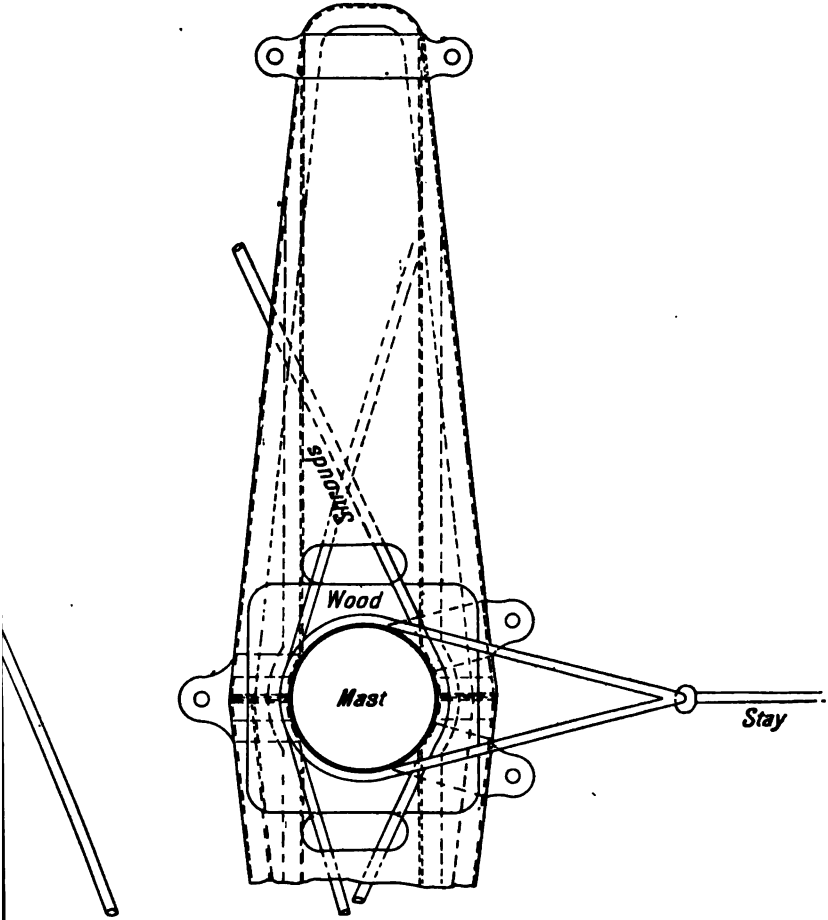
Fig. 151.—Derrick upon Ventilator.

Hatches.—The construction of the sides and ends of hatches has already been fully dealt with and illustrated in our remarks upon "Beams," p. 138. There is no doubt that many a ship has foundered through no other cause





Plan of D



Plan of Outreaches for Derricks

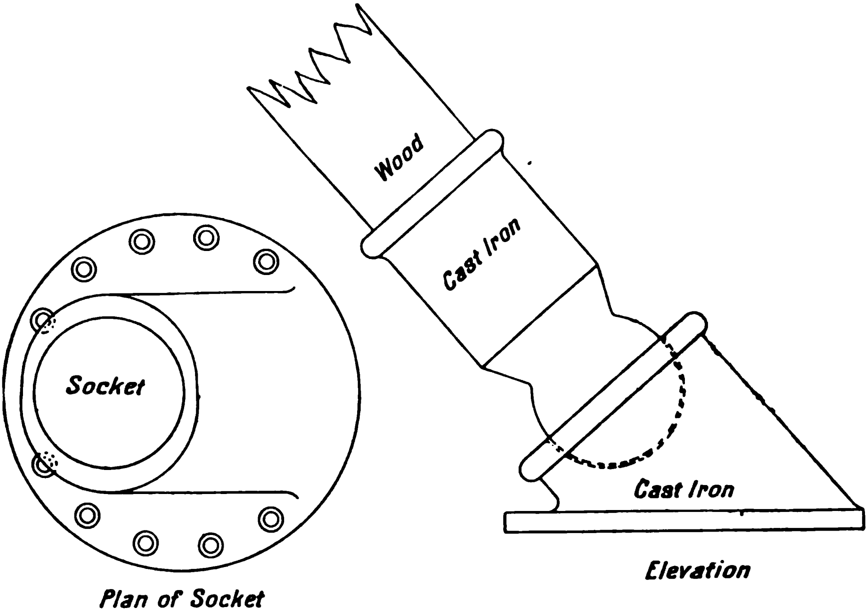


FIG. 154.—Cast Iron Socket on Deck for Strong Derrick.

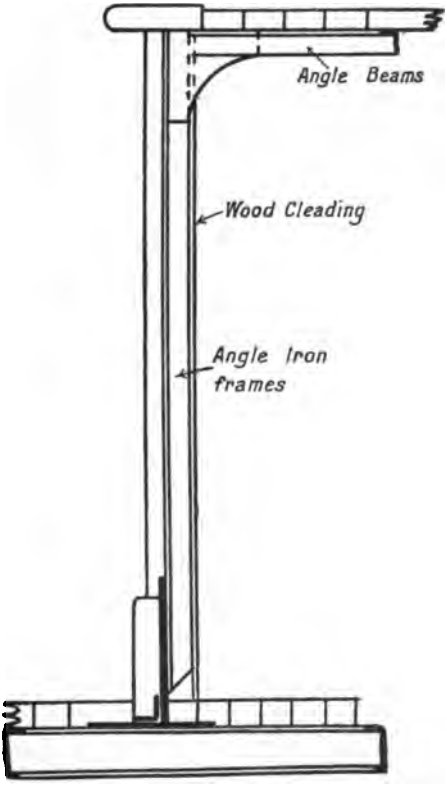


FIG. 155.—Composite Deck House.

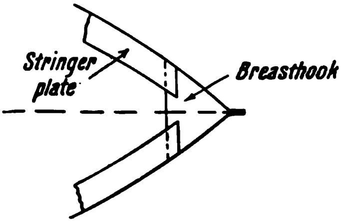


FIG. 155A.

than the inefficient construction of hatches, which have been unable to bear the weight of huge volumes of water which so often fall upon them when heavy seas are shipped. It is of the utmost importance that ample support be given to the deck in way of all hatches, or large deck openings, as the continuity of the beams is destroyed in all such localities. It is not sufficient that the beam ends be well connected to the hatch coaming plates, but, owing to the impossibility of fitting the usual centre-line pillars, these structural requirements, or some equivalent substitute, should be introduced at the hatch sides. Figs. 58 A and B show an excellent method of dispensing with hatch side pillars entirely, the support to the deck and hatch coamings being obtained by large plate brackets, which both tie and support the deck in relation to the sides of the vessel.

Hatch coamings of considerable or exceptional height should be supported by brackets or stays of some kind. Fig. 58 B illustrates a system of supporting such hatch coamings by bulb plates spaced about 6 ft. apart. Not only should the coamings be of ample strength, but the hatch covers should be at least 3 in. in thickness, supported upon strong fore and aft, and, where necessary, transverse bearers. In the case of short hatches, one fore and aft middle-line, and, if necessary, two side bearers, or "fore and afters," as they are technically called, should be fitted. These may be of wood, 6 in. or 8 in. square, fitted into shoes on the hatch end coamings, or they may consist of bulb angles, tee bulbs, etc. Where the hatches are of greater length, transverse assistance is given to the deck, and the hatch sides are prevented from collapsing, by fitting transverse web plates, which should be stiffened on their upper and lower edges by angles or half-round iron, and fitted into slides, several methods of which are illustrated in fig. 101. Tarpaulins, fastened to the hatch sides by cleats, battens, and wedges, are fitted to weather deck hatches of all vessels.

Deck Houses.—Deck houses for accommodation, etc., are frequently built entirely of steel with steel frames and beams. This certainly makes the strongest house. Where, however, they are built of wood, it is advisable that they be framed with steel or iron bars, and have steel coamings well attached to a deck tie plate or to the steel deck if such is fitted. This affords a substantial framework upon which to lay the wood construction, and is illustrated in fig. 155.

Poop and Bridge Front Bulkheads.—All steel poop and bridge fronts should have thick coaming plates well connected to the deck. The upper plating may be somewhat thinner. The stiffening should be made by angle bars of at least the size of the main frames, spaced not more than 30 in. apart, with brackets top and bottom. Fig. 21 and remarks, pp. 47 and 48, further describe and illustrate the construction of these parts.

Tunnel and Casings.—The tunnel, by means of which the propeller shaft is encased, should be thoroughly watertight from the engine room bulkhead to the aftermost bulkhead, with stuffing boxes upon each. As it is advisable to have the engine-thrust in free and easy communication with the engine room, the after engine room bulkhead is usually recessed for this purpose. The tunnel should be stiffened to resist the weight of the cargo which may rest upon it, by means of angles bent transversely round it on the inside, or by solid half-round iron bars on the outside. These should be spaced not more than 3 ft. apart. As far as possible, hold pillars should be kept off the tunnel, by arranging them zigzag one on each side. Where this cannot be avoided, double angle stiffeners must be fitted under the pillars. The tunnel under the hatchways should be sheathed with wood, or the plating increased in thickness, to protect it from blows from cargo in the operation of loading or unloading. It should be large enough inside to permit of easy access to all the shaft bearings.

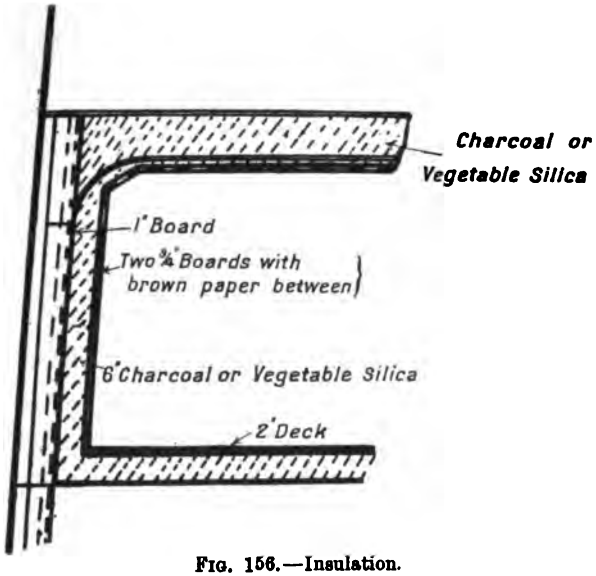


FIG. 156.—Insulation.

When the tunnel stands upon a centre keelson, the tunnel floor is usually laid on the top of the centre keelson, thus permitting more easily of being made watertight (see fig. 65).

Casings enclosing engine and boiler openings should be stiffened by angles or half-round iron on the inside, and if exposed to the weather, the strength must be sufficient to afford ample protection to these vitally important deck openings.

Breast Hooks.—All stringers, wherever practicable, should be carried all fore and aft, and united at the ends of the vessel by means of *breast hooks* (see fig. 155A). In large vessels, an extra breast hook should be fitted at the stem between each tier of beams for the further support of the shell plating.

Insulation.—Fig. 156 illustrates a system of insulation adopted in the holds and 'tween decks of steamers engaged in carrying dead meat, etc.

Bilge Keels.—A bilge keel is a projecting fin of some kind usually attached to the outside shell plating on the turn of the bilge, the resistance of which, as it oscillates with the rolling movements of the vessel, conduces to the desirable quality of steadiness or easiness, and reduction of the angle of inclination.

It may be constructed in several ways, but in average cargo steamers it usually consists of a bulb plate, 8, 10, or 12 in. in width according to the size of the vessel, riveted between double angles. It may be either riveted through the shell or connected by means of tap rivets. Another method is to connect the bulb plate to the shell by means of a single angle, or by means of a tee bar. But in the event of grounding upon the bilge keel or coming into contact with any kind of obstruction, the first method generally causes least injury to the ship, as the bulb plate simply buckles or bends over the two angles, and usually no injury is caused to the rivets through the shell. In either of the other methods, there is the danger of the tee bar, or angle, being wrenched at the root, and the caulking or riveting damaged and leakage ensuing (see figs. 13, 50, etc.). See description of bilge keels of "Lusitania" and "Mauretania," page 55 and fig. 24.

Bilge keels should be placed so as to give the least possible resistance to propulsion, and kept as clear as possible from shell landings, tank side riveting, etc.

Ventilation.

In every well-constructed vessel a great amount of thought is given to the subject of efficient ventilation, and though the arrangement for ventilation may be more complicated in a passenger vessel, yet it is of equal importance in a purely cargo one.

In every ship where a thoroughly efficient system of ventilation has been installed, there will be provided a free circulation of air in every compartment, whether it be saloon, cabin, or lavatory, occupied by passengers; in every crew space; in every hold space in which cargo of any kind has to be carried; in engine room, boiler room, and shaft tunnel; in bunkers, in every compartment used solely or temporarily for the carriage of water ballast; in peak spaces; in store-rooms, galleys, pantries, etc.; in short, *every* compartment in the vessel should be ventilated.

This is necessary, not only from a sanitary point of view, for the health and comfort of passengers, but because it is an absolute necessity for the engineers and stokers shut up in the bowels of the vessel, for the preservation of perishable cargoes, in order to rid hold and other spaces of obnoxious or poisonous and inflammable gases, and because good ventilation is as efficacious in the preservation of the material of which the vessel is constructed (iron, steel, wood, etc.) as the best patent composition ever put upon a ship.

Ventilation does not solely consist in making a certain number of inlets to, or outlets from, any particular space, as one would sometimes imagine by the way in which it is carried out, but it is the intelligent arrangement of such inlets and outlets, so situated that fresh air is introduced and foul air is expelled. This is usually effected in ships by means of natural ventilation, though, in some cases, forced ventilation, by means of fan draughts or even steam injections, is necessary, in order to rid certain spaces of the foul air which gathers in them.

Innumerable systems and patent arrangements for ventilation have been introduced and are in use, but in a work of this kind it is impossible to examine all these various methods, and we must therefore confine ourselves to the older method of natural ventilation, which may be very efficacious if well arranged.

The best known ventilator is the cowl-head (see fig. 157). It is essential that all ventilators situated upon the weather deck be sufficiently strong to endure without damage the force of heavy seas shipped on deck. In bad weather it is not very uncommon for deck ventilators to be carried away, and the cargo to suffer considerable damage, or discomfort to be brought upon passengers or crew, not to mention the possibility even of positive danger accruing from the continued ingress of water through such openings. Thus, in erecting cowl ventilators upon the weather decks, the coamings or lower plating should consist of thick plates (at least $\frac{6}{20}$ in.) connected to the deck by a correspondingly strong angle bar. These coamings should be at least 30 in. high. The upper part of the ventilator, which includes the cowl-head, is portable, and is usually made of thinner plating than the coamings, as in very bad weather, when much water is being shipped on deck, it is usual to unship this upper part, and fit into the top of the coamings the plate lid, which is shown in fig. 157 A in a vertical position, where it is kept when not in use. To ensure that the ventilator be now thoroughly watertight, a canvas cover is lashed over the top of the coamings.

When these ventilators are intended to ventilate the hold space of a single deck vessel, the diameter ought to be regulated in accordance with the capacity of the space to be ventilated.

The coamings should be made of welded steel or wrought-iron plates. The diameter of the cowl mouth should be large enough and so shaped as to take in as great a volume of air as possible (say, two or two and a half times the diameter of the coamings). The portable upper part of the ventilator, when fixed on to the coamings, rests upon an iron ledge upon the outside of the coamings, as shown in fig. 157 A; or it may come right down and rest upon the vertical flange of the deck angle. There should be at least two cowl ventilators to each hold, one at each end of the space, and in such positions that they may efficiently act, one for the inlet of fresh air, and the other for the outlet of the hold space air, which is expelled. When these ventilators are situated near to, or against, forecastle fronts, bridge ends, poop fronts, or any other deck erection, they should extend to a height such as will bring the cowl mouth above the top of these erections. Their extreme length necessitates that they be supported by means of stays, either to the deck or to the erections near which they are situated. When a vessel has two or more laid decks, it is usual to ventilate the hold and main deck spaces in a manner similar to that shown in fig. 157 B. The diameter of the ventilator coamings upon the uppermost deck is made sufficiently large to ventilate the whole of the space below the upper deck, supposing no 'tween decks existed. But as 'tween decks do exist, the area of the ventilating opening on the upper deck is reduced by the insertion of a tube leading to the second 'tween decks, the diameter of which is supposed to be large enough to ventilate the lower 'tween decks and hold space. But as the hold space is an entirely separate compartment, the area of the ventilating opening in the upper 'tween decks is again reduced by the insertion of a ventilating tube from the hold space, the diameter of which is in proportion to the volume of such space. It will be evident that, while one ventilator at the end of each hold space may be sufficient in a small single deck vessel, a greater number of ventilators will be required in large vessels with one or more 'tween decks and huge hold spaces. (For the ventilation of steamers carrying oil in bulk, see Chapter III., Section 2.)

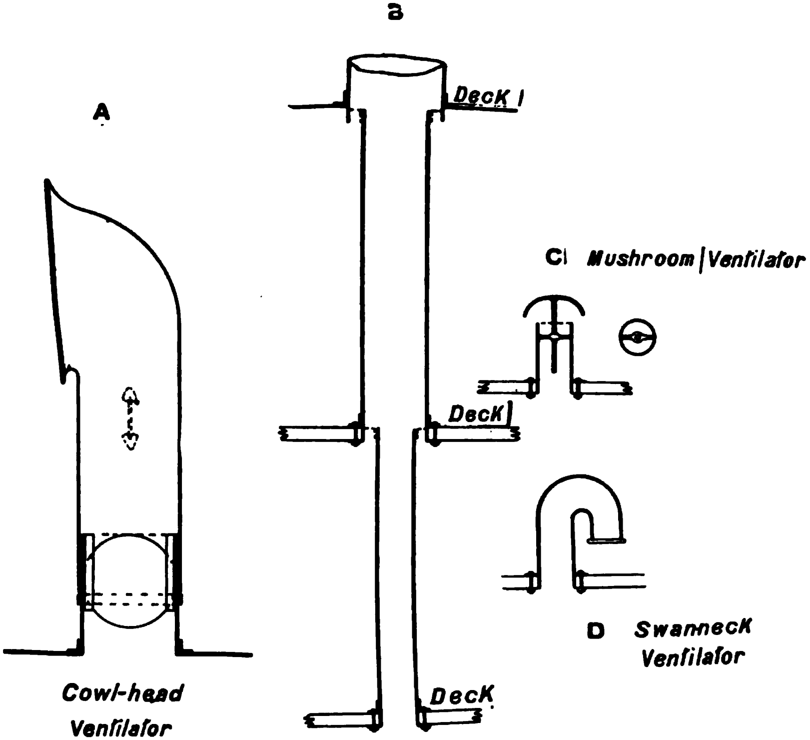


Fig. 157.—Ventilators.

While it may be advantageous to ventilate all spaces occupied by the crew and officers and engineers by means of cowlhead ventilators where the spaces are of considerable size, sufficient ventilation can be obtained in small cabin spaces, galleys, pantries, lockers, store-rooms, lavatories, etc., by means of swan-neck and mushroom top ventilators (see figs. 157, D and C), assisted by louvre openings in the doors. Most of these spaces have the additional advantage of hinged scuttles, which in fine weather may permit an abundant flow of fresh air, and in bad weather may be secured and made thoroughly safe by their solid hinged plate dead-lights.

One of the parts of the vessel which needs particular attention in designing the ventilating arrangements is the engine room. This space is often sadly neglected, as those who have had any sea experience of these vessels know. The recesses in these spaces caused by pocket bunkers, engine room store, etc., and the fact that the light and air opening through the decks is often very narrow, with consequently large flat areas of deck overhead, tends to harbouring of a considerable amount of stagnant air, owing to the ventilators, as a rule, being inserted through the top of the casings, and failing to rid the space of the obnoxious air in the engine room wings. In addition, engine rooms often get unbearably heated, owing to the proximity of the boilers. The boiler room also needs ventilating, and this is largely effected by the iron gratings on the top of the casings, and cowl-head ventilators of very large diameter. One or more cowl-head ventilators ought to be fitted into the tunnel, one as far aft as possible. The other spaces previously mentioned may be ventilated by one such ventilator as illustrated in fig. 157, C and D.

Pumping.

Nothing in the equipment of a vessel is of greater importance than a well-planned and thoroughly efficient arrangement of pumping. This is essential for many reasons, all of which ought to be thoroughly considered and thought out in the design of such an arrangement.

In any vessel there is always a possibility of water finding its way into the interior of the hull below the weather deck. This may be due to damage from collision, leakage, damage to deck fittings in heavy weather, drainage from wet cargo, heavy sweating on the inside of the shell plating, decks, etc.—especially where ventilation is inefficient,—drainage from scuppers, etc., etc.

The pumping installation should be capable of speedily ejecting all such water, excepting in cases where collision has made an opening so large that for any pump to cope with the inflow is impossible.

In sailing vessels where there is no steam power on board, all such pumping has to be effected by manual labour. Where the vessel has much rise of floor, so that even under considerable list to port or starboard the water still gravitates to the middle line, there should be at least one hand pump to each hold compartment.*

In order to allow water to drain from one hold compartment to another, it is permissible to fit sluice valves to each bulkhead (when more than one bulkhead is fitted). On no account should a sluice valve be fitted to the collision bulkhead. See fig. 158.

No sluice valve should be fitted to any watertight bulkhead unless it can be reached at all times, on account of the possibility of chips or rubbish getting jammed into the opening and preventing the valve from closing.

To reach the sluice valves upon watertight bulkheads, either a wooden or plated trunk-way must be fitted from the deck above, sufficiently dust-tight to prevent dirt, grain, etc., finding their way from the hold to the valves. All rods working the sluice valves should extend to the upper deck, and be clearly marked with a brass plate cover, so as to be easily found, and fitted with an indicator to show when shut and open.

To ascertain the depth of water in any compartment in any possible condition, a sufficient number of sounding pipes should be fitted. The depth of such water is ascertained by means of a sounding rod lowered inside the pipe. As the frequent thumping of such rods would be likely to eventually seriously damage the shell plating, a small doubling plate should be fitted under each sounding pipe.

If a tube were inserted in a basin of water, and the air sucked out of the tube, the water inside the tube would rise to a considerable height above the level of the water in the basin. This is due to the atmospheric pressure upon the surface of the water in the basin, and the fact that this pressure has been wholly or partially taken from the water inside the tube. Were the tube long enough, and the vacuum so produced absolutely perfect, the water in the tube would rise to a height of about 34 ft., the weight of such a column of water being equal to the atmospheric pressure upon every unit of area on the surface of the water in the basin equal to the sectional area of the tube.

The principle of the manipulation of the hand pump is identical with the foregoing illustration. First of all, there is a long suction tube from the bottom of the vessel up to the pump chamber. The action of the bucket, which is worked by a handle on the deck, is to first pump the air out of the pipe, immediately upon which the water ascends. Were a perfect vacuum produced, it would rise, as previously stated, to

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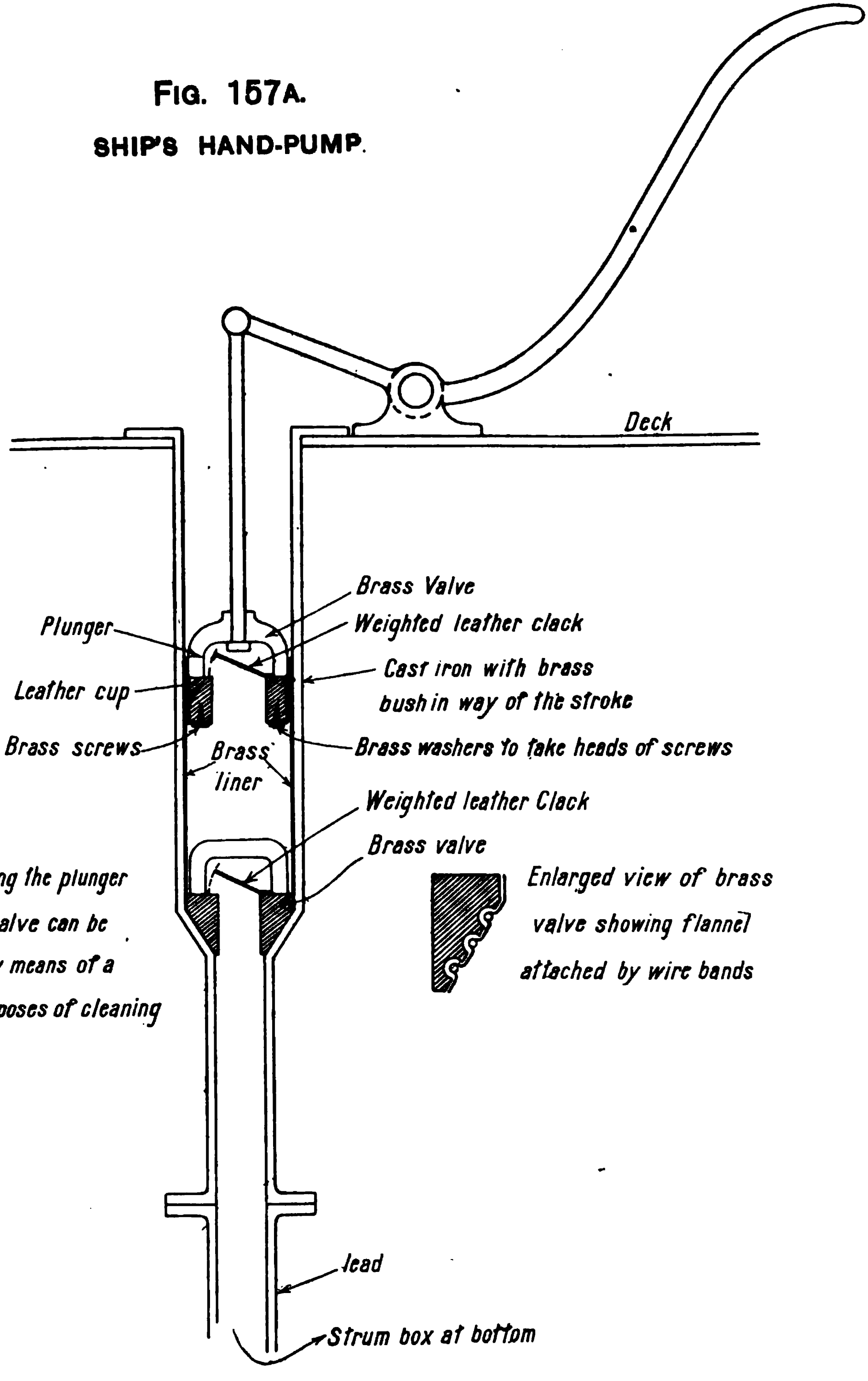
* It may be pointed out that in sailing ships only one bulkhead is usually fitted, viz., the collision bulkhead, and this therefore greatly simplifies the pumping arrangement. As a rule, one pair of pumps to this main hold space is considered sufficient.

These suctions are led from the pump well, which is usually situated just abaft of the main mast. Access is obtained to this well, whenever necessary, by a wooden trunk-way fitted from the weather deck to the bottom of the ship.

FIG. 157A.

SHIP'S HAND-PUMP.



By removing the plunger the lower valve can be ifted out by means of a ook for purposes of cleaning

a height of about 34 ft.; but as it is practically impossible in such pumps to get an absolute vacuum, it is safer never to count upon the water rising above 24 ft. As hand pumps are usually worked from the upper deck, the suction chamber should be deep enough to ensure that the bucket is not more than 24 ft. above the bottom of the hold.

A rose, strum box, or suitable mouthpiece is usually fitted to the lowest extremity of the suction pipe, to prevent any solid matter being drawn into the pump. As a considerable thickness of cement is commonly laid on the inside of the bottom shell plating for purposes of preservation, the cement ought to be dished out in way of the strum boxes so as to bring the bottom of the suction pipe below the level of the cement, and thus as nearly as possible eject all water from the compartments (see fig. 159). The necessity for an ample number of drain holes through the floor plates (limber holes), to allow the water to reach the pumps, will now be apparent.

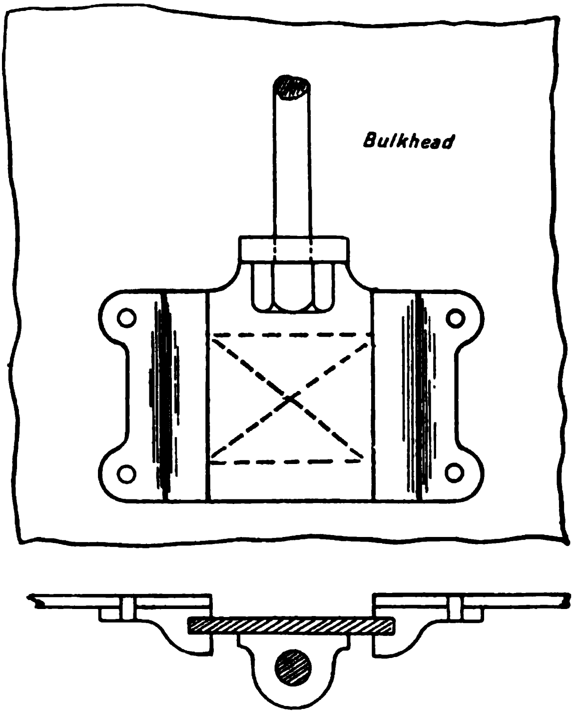


FIG. 158.—Sluice Valve.

A pump is now in existence (Downton's) by means of which several suctions may be led into one suction chamber, and water pumped from any compartment. In sailing vessels having a donkey boiler, these pumps should be arranged so that they may be worked, if necessary, from a steam winch.

Steam Vessels without Double Bottoms.

Screw and paddle vessels have the great advantage of possessing steam power, which is utilized in pumping from the various compartments. Steam vessels without double bottoms should have at least one hand pump and one steam pump fitted in each hold when the rise of floor is considerable.

When there is very little rise of floor, three steam-pump suctions—one as near the centre line as possible, and one in each wing—and at least one hand pump, should be fitted into each hold compartment. If the vessel has fore and after peak water-ballast tanks, a separate steam-pump suction should be led to each. When water is not carried as ballast in these compartments, a hand pump only is required in the fore peak.

No sluice valve must be fitted to the collision bulkhead under any circumstances; indeed, no sluice valve must be fitted to any bulkhead which bounds a water-ballast tank. If the after peak is not intended for the carriage of water-ballast, a sluice valve may be fitted in order to allow any water to reach the pumps in the after hold. The engine and boiler space should be fitted with at least three steam-pump suctions, one at the centre, and one in each bilge, and the Board of Trade requires one hand pump.

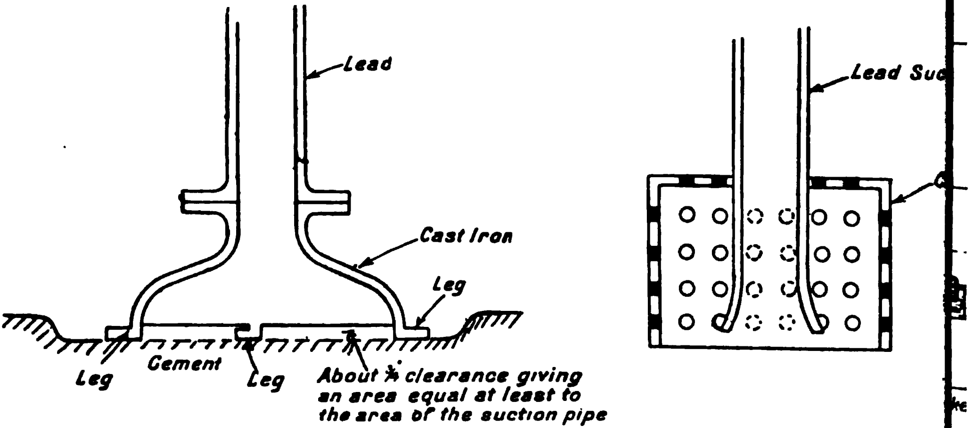


FIG. 159.—Mouthpiece for Suction Pipe with three legs resting upon the cement, which is dished out as shown.

Steam Vessels with Double Bottoms (see fig. 160).

Before dealing with the pumps, the nature of all the spaces or compartments which exist along the bottoms of vessels with double bottoms for the carriage of water-ballast ought to be thoroughly understood.

The double bottom should at least be divided into watertight compartments agreeing with the number of the watertight bulkheads. But this division is often exceeded in practice (see figs. 14, 48, and 160, etc.).

Hence it is necessary that three steam pump suctions — one at the middle line and one at each side — should draw from each of these compartments. Where the rise of floor is considerable only the centre suction is necessary. But at the wing extremities on the outside of double bottom tanks, there are the bilges into which drainage from cargo, scuppers, sweating, etc., may find its way, and pumps must be provided to get rid of such water. A steam pump suction and a hand pump should therefore be fitted to each bilge.

A better system of ridding the bilges of water than is obtained by the common hand pump, is to fit a fly-wheel pump (such as a Downton) connected to the steam pump bilge suction pipes of these compartments.

It is usual and advisable to arrange for about two frame spaces at or near the after end of the engine and boiler space to act as a well into which bilge water may drain. A cock or sluice valve may be fitted through the bulkheads in way of the bilges at each end of this space, so as to allow bilge water in the adjacent holds also to drain into

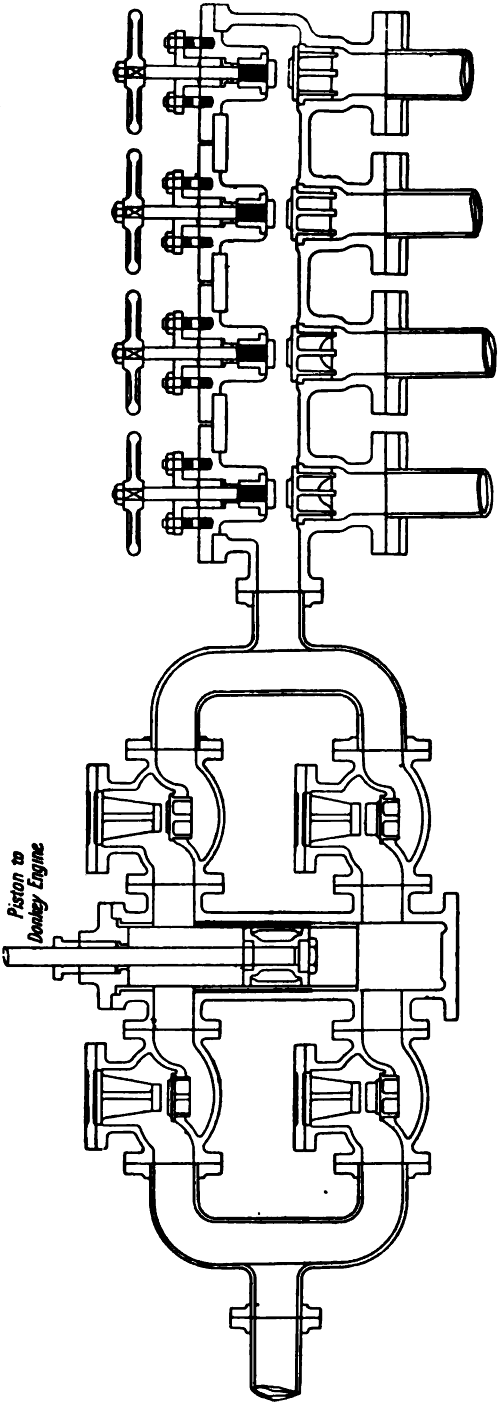


FIG. 161.—Bilge Suction Valve Chest, showing non-return Valves.

the engine-room well. As before stated, such sluice valves or cocks should be always accessible.

The well is in all respects constructed like the double bottom elsewhere, excepting that the floor at each end of it is water-tight, and several holes, 3 in. or more in diameter, are punched through the tank margin plate through which the bilge water flows into the well, or in lieu of this a better arrangement is to fit a non-return valve on the margin plate. When such a well exists, one steam pump suction should be led as near the middle line as possible, and one in each bilge.

The main and donkey pumps should be arranged to draw from the fore peak, and the after peak also if used for water ballast, from double-bottom tanks, wells, bilges, and from hold spaces in vessels without double bottoms. The donkey pump should have a separate bilge suction in the engine room. The steam suction pipes from the various compartments, on reaching the engine room, are led into combined valve boxes or chests, which are in turn connected to the pumps. Fig. 161 shows such a valve chest, and the donkey pump, which is of double-acting type. As shown in the diagram, when it is desired to draw from any particular compartment, the valves to suctions for other compartments can be closed by the valves shown.

A well, similar to that just described for the engine room, is usually arranged at the after end of the after-hold space into which bilge drainage finds its way. A steam-pump suction is therefore necessary for this space also.

Adjacent to this well, another well is usually constructed exclusively for drainage from the tunnel, which in its turn also requires a separate suction, which may be connected up to the hold well suction by a valve box somewhat similar to that illustrated in fig. 161, and which is manipulated from the inside of the tunnel.

A sounding pipe should be fitted on each side of all ballast tanks, with the necessary doubling plate under each, as previously pointed out.

To allow for the exhaust of air in all water-ballast tanks when being filled up, a sufficient number of air pipes should be led to the upper deck, which, if made of 5 in. or 6 in. diameter, instead of 2½ in. or 3 in. as usually fitted, may conveniently, and with great advantage, add to the preservation of the structure, if made to act as ventilators.

Sufficient limber holes should be punched through all floor plates and tank knees, increasing in number towards the suctions, to allow for an ample flow of water to reach the pumps.

All tank floor plates should be perforated with circular holes near the upper extremity, to act as air passages, and for a similar reason the packing pieces under outside strakes of tank top plating should be kept a little short.

Hand Pumps, Steam Suctions, etc.

The following tables taken from Lloyd's Rules will give some idea of the minimum sizes required for pipes to hand pumps and steam suctions.

Tonnage under Upper Deck.	Hand Pump in Holds.	
	Diameter of Barrel.	Diameter of Tail Pipe.
	in.	in.
In vessels under 500 tons, . .	4	2
,, ,, of 500 but under 1000 tons,	4½	2¼
,, ,, ,, 1000 ,, ,, 2000 ,,	5	2½
,, ,, ,, 2000 and above, . .	5½	2¾

Tonnage under Upper Deck.	Engine Room Centre Suction, Separate Donkey Suction, and Hold Centre Suctions.	Wing Suctions in Holds where no Centre Suctions are fitted, and Wing Suctions in E. and B. Room.	Wing Suctions in Holds where Centre Suctions are fitted.
	in.	in.	in.
In vessels under 500 tons, . .	2	2	2
,, ,, 500 tons and under 1000 tons,	2¼	2	2
,, ,, 1000 ,, ,, ,, 1500 ,,	2½	2¼	2
,, ,, 1500 ,, ,, ,, 2000 ,,	3	2¾	2¼
,, ,, 2000 ,, ,, ,, 3000 ,,	3½	3	2½
,, ,, 3000 ,, and above, . .	3½	3½	2¾

Launching.

One of the most important events in the history of a ship is the launch—important, not only because this is her introduction to the element upon which the work of her life will be performed, but because, in the transit from land to water, unless the greatest care and caution are exercised, results of a most disastrous nature may accrue. Instances are on record when the damage received in launching has distinctly contributed to the loss of the vessel at sea, and many a ship has been so injured as to cost her builders thousands of pounds to repair.

The strength of the launching cradle and standing ways, the earth foundation as well as the declivity, length, and camber of the standing ways, are all features in the carrying out of a launch which contribute to the success of this operation.

In shipyard practice the laying of the ways was, and is still, in some of the smaller establishments, left in the hands of the foreman shipwright, whose experience guides him in fixing the declivity, etc., necessary for any particular vessel. But with the vast increase in the sizes of vessels in recent years, the launching particulars are fixed in the ship drawing office, where the whole matter is considered and investigated, and the calculations involved carried out.

One of the greatest dangers in launching a ship is, that in the event of there being too little water on the ends of the ways, she may tilt after her centre of gravity has passed the ends of the standing or fixed launching ways. The fore end of the vessel would then be lifted entirely clear of the sliding ways, and the whole weight of the vessel (less the buoyancy of the water-borne portion of the ship) would then be resting upon the extreme end of the fixed ways, and these, being made of wood, are liable to collapse under the pressure. Moreover, there would be nothing to prevent the vessel slewing across the launching ways by any slight wind or tide, and even leaving the launching ways altogether, bringing about a catastrophe of the most serious nature (see page 120). The enormous pressure thrust upon the bottom, when a vessel tilts, is sometimes sufficient to crush in the plating and do other damage. The ways may be flat or hollow (see fig. 82), and the breadth of the ways for a merchant vessel about 300 ft. long would generally be from about 15 to 18 in.

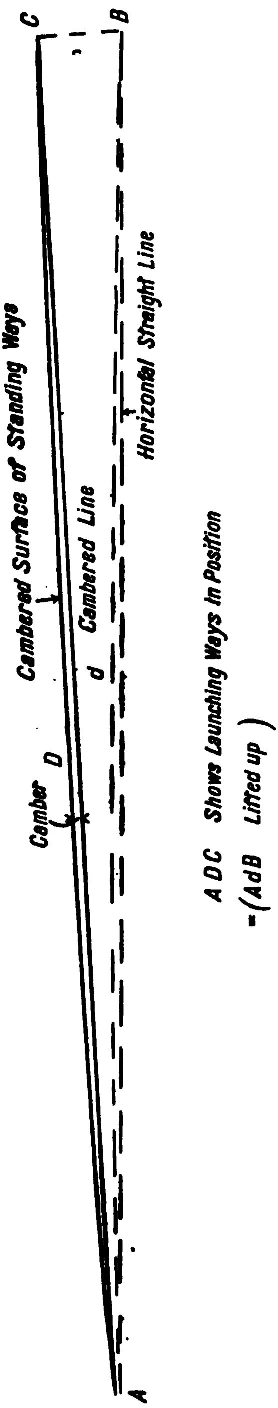


FIG. 162.—Diagram showing Straight and Cambered Launching Ways.

The usual declivity of the keel is about ½ in. or $\frac{9}{16}$ in. per foot of length, and is a perfectly straight line. The declivity of the standing ways may be either perfectly straight, or cambered in the direction of the length. The latter method is commonly adopted.

Fig. 162 shows what is meant by "camber." Let A B be a straight horizontal line, representing the length of the launching ways. Upon it construct an arc of a circle, A *d* B, having a round or camber of, say, 18 in. Now lift A B up to A C, so that it has the declivity desired for the launching ways. A D C will be the form of the surface of the standing ways. The camber varies from 9 in. to 12 in., though for special types of vessels it may be lower or higher than these limits.

It will now be seen that a tangent upon the upper half of the arc of the launching ways must be at considerably less declivity than the tangent upon the lower half of the ways. Hence, in providing particulars of the launching ways, two declivities are usually given when the ways are cambered. The usual declivity of the standing ways runs about ½ in. per foot on the fore part of the ways, to ¾ in. or more towards the ends.

The mean pressure per foot upon the sliding ways ranges up to three tons, seldom over, the average being two tons (see p. 64).

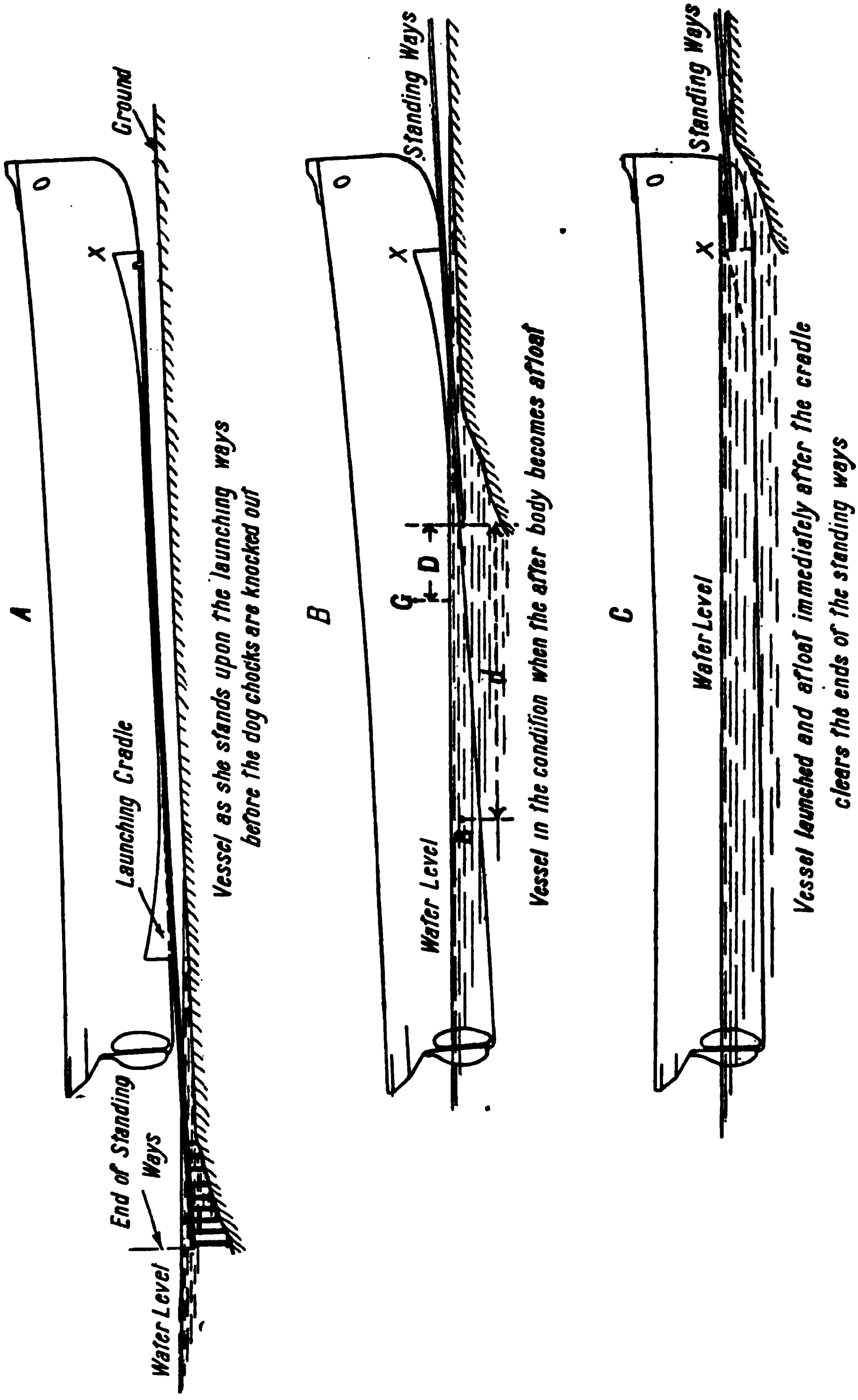
Experience is invaluable in shipyard practice, but the very best is liable to fail under exceptional circumstances; hence launches are not always as successful as they might have been had the vessel's condition been tested by calculation before the operation of launching was performed. Everyone who has seen a ship launched has observed that, at the moment she begins to move after the dog chocks have been knocked out at the fore end, her weight over the whole of the length bears on the launching ways. But as she travels, her after end passes over the end of the ways, enters the water, and eventually becomes afloat, while the fore end bears upon the fore end of the launching cradle (see fig. 163).

The point at which the after end of the vessel becomes water-borne (the transition stage between 163 A and 163 C, namely 163 B) will occur when the moment of the ship's weight, about the fore end of the launching cradle (the sliding ways), X in fig. 163, is exactly equalled by the moment of the buoyancy of the immersed volume of the vessel about the same point X.

The moment of weight is obtained by multiplying the vessel's weight in tons by the distance of her centre of gravity from the fore end of the cradle X, in fig. 163 (*i.e.* weight in tons × G X), and the moment of buoyancy is found by multiplying the buoyancy in tons of the immersed volume by the distance of its centre of buoyancy from the fore end of the cradle also (*i.e.* displacement in tons × B X).

Supposing a ship to be 300 ft. long, her weight on the ways to be 1500 tons, and the distance from her centre of gravity to the fore end of the launching cradle to be 130 ft., then the moment of weight would be $1500 \times 130 = 195{,}000$ ft. tons. When this amount of buoyancy moment exists, it is known that the after end of the vessel is afloat, making allowance for the fact that slightly more immersion is necessary in order to overcome the ship's momentum, which causes her to travel a little further down the ways before her stern lifts.

When the aft end of the vessel enters the water, her weight will be partly borne by the water, and partly by the launching ways. The amount of support afforded by the water is the displacement, and the



Vessel as she stands upon the launching ways before the dog chocks are knocked out

Vessel in the condition when the after body becomes afloat

Vessel launched and afloat immediately after the cradle clears the ends of the standing ways

FIG. 168.—Launching Diagram.

difference between the displacement and the total weight of the ship represents the weight borne by the launching ways. Through not realizing the amount of this pressure upon the fore end of the sliding ways, sometimes the cradle has collapsed through weakness, and the vessel has come heavily down upon her stem, thereby producing considerable damage. Because of this fact, more declivity is given to the after end of the standing ways than the fore end by cambering, the endeavour being to get the vessel over this critical stage as soon as possible, remembering at the same time that the resistance offered by the water increases as the immersion increases.

In calculating the condition of a ship with regard to tipping, the moment of the vessel's weight and the moment of buoyancy are calculated about the end of the standing ways. If, after the ship's centre of gravity has passed over the end of the standing ways, the buoyancy moment (displacement × d) falls below the moment of weight (weight × D), tipping, under such circumstances, will inevitably occur. Care should be taken that a vessel has a reasonable margin of moment (*i.e.* displacement × d should always exceed weight × d) to ensure against tipping, *i.e.* preponderance in buoyancy moment.

If the calculated results show that tipping is likely to ensue, something must be done to prevent this: either the launching ways must be lengthened so that the vessel becomes more deeply immersed when the centre of gravity passes the end of the standing ways, thereby increasing the buoyancy moment (displacement × d), or else weight of some kind must be introduced into the fore end of the vessel; for instance, the fore peak might be filled with water. This latter expedient will have the effect of reducing the ship's weight moment—*i.e.* while it is obvious that, by filling the fore peak, the weight has been increased by the tons of water in this space, yet the ultimate result upon the weight moment will be a reduction, owing to the effect produced by the addition of such a weight at such a leverage from G, in its marked effect in drawing G forward. (See full description and sketches relating to the launch of the "Mauretania," page 55.) Such a case could be further helped by increasing the declivity of the after end of the ways.

The danger of tipping is considerably less in full-lined vessels than in vessels with fine lines, the buoyancy moment naturally being proportionately much greater in the one case than in the other.

The danger of a ship coming to a standstill in her course down the launching ways may be caused by unfairness in laying the ways, or by too little declivity, or sinkage of the earth, or by bad or insufficient tallow in frosty weather.

TEST QUESTIONS AND ANSWERS.

The method adopted here has been to give complete sample answers for nearly one-fourth of the total number of questions, and after that to indicate references and illustrations in the text to enable the student to furnish an answer for himself.

For examination work, endeavour to combine brevity and conciseness with completeness of answer.

It is well to remember that many questions are more satisfactorily answered by a sketch than by a lengthy written description.

Question 1.—Give a list of the principal sections of steel and iron rolled in the "mills," and suitable for the construction of ships. State where each is usually employed.

Ans.—1. *Plain plates*, used for shell, decks, tanks, stringers, bulkheads, masts, pillars, etc.

2. *Chequer plates*, for decks, platforms, etc.

3. *Plain angle bars*, used for frames, reversed frames, beams, stringers, keelsons, bulkhead stiffeners, and for connections in every part of the vessel.

4. *Bulb angles*. These may be used for frames, beams, bulkhead stiffeners, keelsons, stringers, etc.

5. *Plain tee bars*, used for beams, stiffeners, stanchions, etc.

6. *Butterly bulbs* or *tee bulbs*, used chiefly for beams.

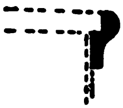
7. *Bulb plates*, used in conjunction with angles for beams, keelsons, stringers, stiffeners, etc.

8. *H bars* or girders, used for strong beams, keelsons, and pillars.

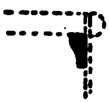
9. *Z bars*, used for frames and bulkhead stiffeners.

10. *Channel bars*, for frames, beams, bulkhead stiffeners, and pillars.

11. *Half round*, *convex iron*, and *flat bar*, for mouldings and sometimes for stiffeners of casings in passage-ways where sharp angle stiffeners might be dangerous.



12. *A patent section for hatches*, combining in efficiency, both the usual rest iron for hatch covers, and moulding.



13. *Rest iron*, which is attached to the inside of hatch coamings to support the covers.

14. *Round iron*, for pillars, stanchions, etc. This may be solid or hollow.

Question 2.—What is a bar keel, and how are its parts connected?

Ans.—A bar keel is a solid bar of forged iron under the heels of the frames, extending in a fore-and-aft line along the bottom of a vessel from stem bar to stern frame, to each of which it is united by means of scarphs. It is made up of lengths varying from 20 to 50 ft. or more, which also are connected to each other by similar scarphs. The depth of such a keel is usually about three times its thickness, but it should never be less than to permit of two efficient rows of riveting. (Sketch fig. 85, showing riveting and scarph.) It is connected to the hull solely by the garboard strakes; hence it is sometimes termed a "hanging keel." This keel is much less adopted than formerly, except in small vessels. The butts of the garboard strakes should be kept well clear of the keel scarphs. The length of the scarph should be about nine times the thickness of the keel.

Question 3.—What is a plate keel, and how are its parts connected?

Ans.—A plate keel is a broad thick plate, usually about 36 inches wide, laid horizontally in a fore-and-aft line from stem to stern immediately under the frame heels. It is necessarily a thick plate, because, being the lowest extremity of the vessel, it suffers most wear and tear from docking, grounding, etc. In addition, in conjunction with the centre through-plate keelson standing upon such a keel, to which it is connected by thick angles (the system adopted in cellular double bottom vessels), it contributes important longitudinal strength. It is connected to the garboard strakes as shown in the sketch. (Sketch keel, garboard strakes, centre through-plate, tank top centre strake, and connecting angles from fig. 7.) It is preferable to make the plate keel an outside strake, being then most easily removed in the event of damage.

The lengths of plating making up the total length, are connected, either by straps at least treble-riveted, or by overlap butts treble-riveted. Sometimes, for strength requirements, it is doubled and even trebled in thickness (see figs. 22 and 36). The connection of the keel plate to the stem bar and stern frame is effected by moulding the keel part of such forgings or castings to the shape of the vessel where the keel blends into them, and by dishing the end keel plates so as to bend round them. The keel parts of both stem bar and stern frame are usually notched out about ⅝ in. to form a check at the point where the keel plates terminate. This keeps the plate flush with the bottom of the forgings (or castings, as the case may be). The connection is made by through riveting. (See fig. 132.)

Question 4.—What is a side bar keel? Describe its construction.

Ans.—A side bar keel, like a bar keel, is situated in a fore-and-aft line along the middle of the bottom of a ship, under the frame heels, and is made up of two slabs of forged iron, equal in depth to an ordinary bar keel, one on either side of a centre through-plate, which extends from the bottom of the keel to at least the top of the floors. (See fig. 121.) The side bars should be in as long lengths as possible, while the centre through-plate is made up of plates at least seven frame spaces in length. The total thickness of the keel should be the same as for a solid bar keel. The butts of side bars and centre through-plate should be kept well clear of the garboard strake butts; all butts in adjacent strakes or slabs should be kept two frame spaces clear of each other. (Sketch fig. 86, showing how side bar keel is scarphed into stem and stern posts.)

Question 5.—Describe the principal kinds of transverse framing.

Ans.—(1) Ordinary frame and reverse bar fitted thus (sketch section in fig. 1) in conjunction with one or more tiers of beams, a floor plate, and a pillar; spaced at fore-and-aft intervals of from 20 to 36 inches.

(2) Or, in lieu of the frame and reverse bar, an equivalent channel bar, Z bar, or bulb angle.

(3) Or, where more than one tier of beams is required, one of the lower tiers may be omitted by increasing (*a*) the efficiency of the frame legs by fitting a deeper frame and reverse frame united thus (sketch section as shown in fig. 7), or in lieu of these two bars, an equivalent channel bar, Z bar, or bulb angle may be substituted; (*b*) by introducing web frames at intervals of about six frame spaces.

Question 6.—What is a garboard strake, and why is it a thick strake of plating?

Ans.—The garboard strake is that thick strake of shell plating adjacent to the keel on either side, whether the latter be of bar or flat plate type.

The necessity for stout plates with which to connect a bar keel to the hull of a ship is apparent. An efficient connection could only be obtained by having garboard strakes of proportionate thickness to such a keel. This is necessary in order to provide satisfactory holding of the heads and points of the rivets of large diameter which are required through the keel, and also for properly closing up the work (as the fore-and-aft distance between these large rivets is considerable), so as to get a good firm caulking edge along the bottom of the garboard strake, which terminates about ½ in. from the bottom of the keel proper.

Similarly, a flat plate keel being a very thick strake of plating as compared with the ordinary bottom plating, the garboard strakes should be of proportionate thickness, so as to get a satisfactory rivet connection (as the thicker plate usually determines the size of the rivets) and in order to blend the thickness of the keel strake into the bottom plating.

Question 7.—What is meant by "framing," transverse and longitudinal?

Ans.—While enormous strength is contributed by an ordinary well-arranged shell plating, it is only possible for it to develop its full strength and efficiency when it is supported and held to its work by a system of well-disposed girders on the inside known as framing. These girders are arranged—

(1) To completely girth the vessel transversely on the inside of the shell plating at intervals of from 20 to 36 inches. This is known as transverse framing, each such girder being called a transverse frame.

(2) To extend in a fore-and-aft direction between bilge and bilge from as near the stem as possible to as near the stern as possible. These are known as keelsons, and constitute one part of the longitudinal framing.

(3) To extend in a fore-and-aft direction from stem to stern between the bilge and the upper deck on each side of the vessel, so as to form continuous girders right round the vessel. These girders are termed stringers, and constitute the other part of the longitudinal framing.

Question 8.—What is a floor plate?

Ans.—A floor plate is a transverse vertical web of plating extending from bilge to bilge, riveted to the frame at its bottom edge, and to the reverse frame at the upper edge, forming a girder for the support of the bottom plating in resisting possible deformation due to the vertical water pressures. In vessels with ordinary floors, these plates are fitted upon every frame, and are carried in a fair curve round the bilge to a height equal to at least twice the depth at the middle line, and of the breadth of the frame at this part, where the floor is tapered off in thickness, so as to allow the frame and reverse frame to close up as they unite to form the frame leg. When the floors are made up of two plates, the union is usually effected by means of a treble-riveted lap. In cellular double bottoms, the floors are placed upon every, or each alternate, frame, and extend from inner to outer bottom, and are perforated by manholes. Outside the margin plate, bracket floors are continued up the bilge, by which means an efficient connection is obtained between the frame legs and the bottom of the vessel. Sketch floors from figs. 1 and 2.

Question 9.—What is the function of a beam, and how is it connected to the framing?

Ans.—The function of a beam is—

(1) To unite the frame heads, thereby preserving their distance relationship. They therefore act as struts and ties.

(2) To provide the means of carrying the deck, whether it be of wood, iron, or steel.

(3) To support, in conjunction with the pillars and other strengthening, heavy deck weights, hatch coamings, etc.

The connection to the frames is made by either welded or plate knees. The depth of the knee should be such as to permit of a sufficient number of rivets for efficient connection—never less than 2½ depths of beam, but better 3 depths. In special cases even deeper knees are required.

Sketch welded knee, fig. 94, and bracket knee, fig. 95.

See also knees to figs. 97–99, 102, 104.

Question 10.—What is a keelson? Describe its function in the ship structure. When is it termed "continuous," and when "intercostal"?

Ans.—A keelson is a longitudinal girder capable of a variety of forms, extending in a fore-and-aft direction along the inside of the bottom of a vessel, between bilge and bilge.

It is continuous when it extends without interruption from end to end of the vessel, either on top of the floors (see centre keelson, figs. 4 and 5), or when it stands upon the outer shell plating with the floors butting on either side of it (see centre keelson, figs. 2, 6, and 7, and centre and side keelson in double bottom, fig. 36).

It is an intercostal keelson when it is fitted between continuous floors (see main side keelson, fig. 5, also side keelson in double bottom, fig. 6, and intercostal side keelson, fig. 36).

Its function is to stiffen and support the bottom plating in resisting longitudinal bending, and possible local deformation due to the bottom water pressures, either directly, as in those cases where it comes into direct connection with such plating, or indirectly, by assisting the transverse framing (which it binds together) in supporting the shell. (Sketch figs. 119–122, forms of keelsons.)

Question 11.—What is a stringer? Describe its function and location in a ship.

Ans.—A stringer is a longitudinal girder capable of a variety of forms extending in a fore-and-aft direction along the sides of a vessel between bilge and upper deck. (Sketch double angle stringer with bulb plate between, standing on frame.) It may be continuous, or partially intercostal if fitted between the frames. (Sketch in section and plan continuous angle on frame riveted to plate notched out for frames and fitted close to shell. See stringer, fig. 58.) In addition to those stringers situated between the bilge and the lowest tier of beams, thick stringer plates are fitted to the extremities of all tiers of beams, which more effectively distribute the transverse support furnished by such beams, while at the same time enormous stiffness is afforded to the shell plating. The function of a stringer is to support the shell plating, in conjunction with which it contributes great longitudinal strength, especially when the vessel is subject to large angles of inclination, thereby resisting longitudinal deformation. By tying together the transverse frames, it considerably assists that section of the structure also in its work. (See stringers in figs. 3, 4, 36, 54, etc.)

Question 12.—Under what conditions may side stringers be dispensed with?

Ans.—The stringers between the bilge and lowest tier of beams may be dispensed with by distributing the sectional area of the material which they represent into the frames and shell plating. By increasing the depth and thickness of the transverse framing, the latter is able to more rigidly support the shell plating. This, in conjunction with an increase in the thickness of the shell plating, renders the vessel probably as strong as, if not actually stronger than, with stringers in the usual way.

Question 13.—Enumerate the principal kinds of pillars?

Ans.—The principal kinds of pillars are—

(1) Round solid iron pillars with welded heads and feet to take at least two rivets.

(2) Hollow iron pillars with solid welded heads and feet to take at least two rivets.

(3) Solid half-round or flat iron pillars, usually in cabins, with welded heads and feet with two rivets in palm.

(4) Channel bar, tee bar, or H bar pillars with bracket plate connections at heads and feet.

(5) Built pillars, usually for wider spacing than the foregoing, are made up of two channel bars or two tee bars back to back.

(6) Steel tube pillars, and pillars built of plates like steel masts, connected at lower extremity to a thick plate which is riveted to inner bottom plating. By means of an angle ring, the connection of the pillar to the thick plate is made by tap rivets, so as to prevent all possibility of water finding its way through leaky rivets perforating the inner bottom plating, to the inside of the tube pillars.

Question 14.—Are pillars absolutely necessary? If not, under what conditions can they be dispensed with?

Ans.—Pillars are absolutely necessary in all vessels for the reasons given in answer 15, unless an efficient means of performing their work can be substituted.

Pillars may be (1) partially or (2) entirely dispensed with in the following manner:—

(1) By supporting the deck and beams by means of a continuous girder on each side of the centre line (in line with, and forming part of, hatch coamings preferable), and holding the same to their work by widely spaced steel or iron tube, mast, or built pillars, well bracketed to inner bottom, or, in the case of tube pillars, connected to a thick plate by means of an angle ring round the foot of the pillar, the thick plate being riveted to the tank top plating.

If the vessel has ordinary floors, the large pillars should be bracketed to a side keelson specially strengthened, if necessary, in way of same.

(2) By reducing the beam span by fitting very large brackets (or some equivalent) to the head of the frames at intervals, which, when riveted to the beams, act as cantilevers supporting the deck. Such brackets, to act as efficient substitutes for pillars, must be several feet in depth and several feet in outreach. (See figs. 58, A and B.) Very efficient brackets, connecting the frame legs to the inner bottom or floors, are also necessary.

Question 15.—What is the function of pillars?

Ans.—The function of pillars is to hold the decks and bottom of a ship in correct distance relationship, so as to enable the whole structure to act in unison. Pillars are therefore both struts and ties. They assist the beams in carrying heavy deck weights by distributing the stresses to the lower parts of the structure. Similarly, they distribute the thrust of the bottom water pressures to the upper works. Pillars, however, for the latter reason, are principally required in vessels with shallow ordinary floors—the usual double bottom system of construction being sufficiently strong in itself, if well connected to the frame legs. By supporting the beams at the middle of their span, pillars are of importance in assisting the frames to prevent deformation due to horizontal water pressures.

Question 16.—What is the function of shell plating?

Ans.—The function of shell plating is—

(*a*) To provide a watertight skin or covering over the framework of a ship.

(*b*) To contribute the largest and most valuable proportion of strength to the ship girder. Hence the importance of an intelligent and judicious disposition of the material available, and for the most efficient rivet connections at both edges and butts of all such strakes of plating.

Question 17.—Which are the most valuable parts in the shell-plating?

Ans. The most valuable parts of the shell plating are—

(*a*) The sheer strake, which is the strake of shell plating in way of the strength deck (usually the upper deck), and topside two or three strakes of plating generally.

(*b*) The bilge plating.

(*c*) The keel plate garboard strake and bottom plating.

In the foregoing localities, they contribute most in producing moment of inertia of ship girder section; and as the stresses are severest in the upper and lower extremities of such girder, the desirability of fitting thicker strakes in these localities will be obvious.

Question 18.—Prove approximately by figures that the weight of the highest possible column of water produced by a perfect vacuum in a hand pump suction pipe is equal to the atmospheric pressure.

Ans.—Assume suction pipe contains 4 sq. ins. 1 cub. ft. fresh water = $62\frac{1}{2}$ lbs Height of water in tube in which perfect vacuum has been produced = 34 ft.

$$\therefore \text{ Volume of column of water} = \frac{4 \times 34 \times 12}{1728} = \text{cub. ft.}$$

$$\therefore \text{ Weight of column of water} = \frac{4 \times 34 \times 12}{1728} \times 62\tfrac{1}{2} \text{ lbs.} = 59 \text{ lbs.}$$

$$\therefore \text{ Weight of column on 1 square inch} = \frac{59}{4} = 14{\cdot}75 \text{ lbs.} \quad \textit{Ans.}$$

See p. 202.

Question 19.—What is meant by a classification society, a classed ship, an unclassed ship?
See pp. 1–6.

Question 20.—What is the relationship between "class" and load line assignment?
See pp. 1–6.

Question 21.—What is the standard of strength upon which all load line assignment to British vessels is based?
See pp. 3, 4.

Question 22.—Compare the qualities of mild and high-tensile steel. In what parts of the structure would it be of advantage to have high-tensile steel, and for what reason?
See pp. 52–54, *and fig.* 23.

Question 23.—Illustrate by sketches the principal structural features of a turret steamer, and show wherein it differs from an ordinary three deck steamer of similar dimensions.
See pp. 69–75, *and figs.* 40–47 *and* 59, 60, *etc.*

Question 24.—Describe and illustrate the principal structural characteristics of "the cantilever-framed self-trimming steamer."
See pp. 78–80, *also Plate IX. and figs.* 51, 52.

Question 25.—What is a cellular double bottom tank? Describe its construction.
See pp. 11, 12, 15, 53, 102–4, 132–3. *Illustrate by sketching the cellular double bottom of fig.* 7.

Question 26.—What is a M'Intyre tank? Describe its construction.
See pp. 10, 101–2. *Illustrate by sketching the M'Intyre tank of fig.* 50.

Question 27.—Sketch a cellular double bottom tank from centre line to upper edge of outside margin plate brackets.
State clearly which parts are continuous and which are intercostal.
Give approximate scantlings of material, and state size and spacing of rivets.
Sketch the cellular double bottom of fig. 7. *For construction, see pp.* 11, 12, 15, 53, 102–4, 132–3; *scantlings, see p.* 30; *rivets and riveting, see pp.* 116–7, 125–6, 129.

Question 28.—State which rivet holes in a frame bar are punched before being bent, and which are left until a later stage. Give reasons in each case.
See p. 126.

Question 29.—Describe what is meant by "deep framing" and "web framing." Illustrate all the forms of deep framing with which you are acquainted.
See pp. 134–5, 19–21, *and figs.* 6, 7, 93, 61, 42, 44.

Question 30.—Describe and illustrate the construction of hatch coamings, showing how the half beams and coamings are supported. Show a common method of strengthening the deck at hatch corners.
See pp. 138–140, 164. *See figs.* 96, 100, 101, 129.

Question 31.—Sketch all the methods of connecting beams to the frames which are in common use. Give dimensions in each case.
See figs. 94, 95, 97, 98, 99, 102, 104. *For description see pp.* 135–143. *See also fig.* 61 *and p.* 92, *and fig.* 58, *p.* 88.

Question 32.—Under what circumstances should beams be fitted to every frame, and when may they be fitted to alternate frames?
See pp. 135, 143, 162, 90, 165.

Question 33.—In the event of a steel deck being sheathed with wood, how should the plating be arranged? In the case of an unsheathed steel weather deck, how should the plating be arranged? Give reasons in each case.
See pp. 164, 165; *also figs.* 4, 7, 36, 54, 101.

Question 34.—Illustrate in detail how the tank margin plate of a large vessel is formed, and how it is connected with the adjacent parts of the structure.
See pp. 12, 92, *and figs.* 2, 52, 54, 60, 60A, 61.

Question 35.—Show how an upper deck stringer plate is fitted and connected with the beams and sheer strake. Give section and plan, and show riveting.
See figs. 3, 4, 36, 60B, 129.

Question 36.—Sketch all the forms of rivets in common use, and mention the special qualities or disadvantages of each kind.
See figs. 76, 77, and *pp.* 109–111.

Question 37.—Discuss the value of a strapped butt (single and double straps) *versus* a lapped butt. Show how you would calculate the strength of a butt connection. Show clearly what is the maximum limit of the strength of a lapped and strapped butt connection.
See pp. 112–116, *and fig.* 79.

Question 38.—Show by sketch the spacing of rivets in a butt, a seam, and through a frame in the outside shell plating. Give thicknesses of plates and size of rivets and figured dimensions for rivet spacing.
See pp. 114–118, *and fig.* 80.

Question 39.—Sketch a watertight door in a 'tween decks.
See fig. 127.

Question 40.—What is a bilge keel? Sketch and describe the construction of a bilge keel in a large steel ship, also one in a vessel of average size.
See p. 198.

Question 41.—Sketch a good arrangement of butts of bottom plating for a vessel where the plates are nine frame spaces in length.
See fig. 130.

Question 42.—How may the use of packing iron be avoided in ship construction? State the disadvantages of its use.
See p. 169, *also figs.* 101, 39, 42, etc.

Question 43.—Describe the construction of a bulkhead, showing how it is connected to shell, decks, and bottom, stiffened and caulked.
See pp. 154–161, 91, *and fig.* 124.

Question 44.—What is a bulkhead liner? Why is it fitted? What alternative may be adopted?
See pp. 158–160, *and figs.* 125, 126.

Question 45.—Sketch an arrangement of upper deck plating, stating the dimensions of the vessel. State dimensions and scantlings of plates, width of butt laps and seams, and diameter of spacing of rivets. How is compensation for loss of strength effected in way of an opening in the deck?
See fig. 129, *and pp.* 162–165, 137. *See also "Steam Collier," p.* 87.

Question 46.—Show the construction of an ordinary steel mast for a cargo steamer.
See p. 189, *and fig.* 148.

Question 47.—Describe, with sketches, how the cast-steel shaft brackets of a twin-screw ship are secured in place.
See figs. 139–142, *and pp.* 178–179.

Question 48.—Describe and illustrate by sketches all the kinds of ventilators with which you are acquainted. State where each is used. Show by a profile sketch and deck plan (1) a good arrangement for ventilating the holds on ordinary cargo steamer, (2) on an oil-carrying steamer. Describe special features in each case.

See pp. 198–201, *and fig.* 157 ; *also pp.* 96, 100–101, *and fig.* 65.

Question 49.—Describe efficient systems in common use for supporting derricks at heels.

See pp. 189–191, *and figs.* 151, 152, 154.

Question 50.—Illustrate by a sketch the method of making a continuous keelson (1) bulb plate and two angles, (2) plate and four angles, watertight in passing through a bulkhead.

See fig. 124.

Question 51.—How should (1) a blind hole, (2) a loose rivet be remedied? State what methods should not be permitted.

See pp. 108, 109.

Question 52.—In cases where shell seams are double riveted, when is it preferable to have two rivets through a seam on the frame, and when one? And why?

See pp. 117, 126.

Question 53.—In punching two plates or bars which have to be connected, what would influence you in determining from which side to punch them?

See p. 126.

Question 54.—Why are exposed plated weather decks often of iron, while the unexposed parts are of steel?

See p. 164.

Question 55.—Explain the term "compensation" as used in shipbuilding? Give as many illustrations as you can.

See pp. 19–22, 71–73, 87–93, 158–161, 164, 169–171, 188–189 ; *also figs.* 126, 6, 7, 129, 130.

Question 56.—What is the meaning of "a doubling" in ship construction? Give as many instances as you can showing where doublings are fitted.

See pp. 164, 158–160, 169–171, 53–54, 67 ; *also figs.* 23, 22, 36, 125, 126, 129, 130.

Question 57.—What is a "stealer," and why is it worked in the shell plating?

See p. 172.

Question 58.—What arrangements are made in a ship's structure to speedily get rid of deck water?

See p. 166. *Also include freeing or water ports, and also sometimes open rails at intervals in the bulwarks.*

Question 59.—How is watertightness obtained in decks against the shell plating (1) on weather decks, (2) on steel 'tween decks?

See p. 165.

Question 60.—What is panting? What methods are usually adopted to prevent panting?

See pp. 191–4.

Question 61.—Show a good arrangement for lowering a cargo steamer's top-mast.

See p. 191, *and figs.* 149, 150.

Question 62.—Show by a sketch (*a*) how plated bulwarks are stiffened and supported, (*b*) how high hatch coamings are stiffened and supported.

See pp. 171, 196, *and figs. mentioned thereon.*

Question 63.—Describe how the scantlings of a ship of known dimensions and type are determined by Lloyd's. Which parts of the structure are governed by the 1st and 2nd numerals respectively?

See pp. 22, 23, 31, 32.

Question 64.—Describe the laying of a wood deck (1) on the deck beams, (2) on a steel deck. Show by sketch good arrangement of butts. Give particulars of fastenings, choice of timber, and precautions to prevent decay.
See pp. 165, 166, *and fig.* 129.

Question 65.—What is a sluice valve?
,, a strum box?
,, a Downton pump?
,, an air pipe?
,, a sounding pipe?
What are limber holes?
Why are air passages necessary in double bottom tanks?
See pp. 202–3 *and* 206, *and figs.* 158, 159, and 160.

Question 66.—Describe and roughly sketch an arrangement for pumping the water out of the several compartments of a cellular double bottom tank.
See pp. 204–5. *Sketch from fig.* 160.

Question 67.—Describe an efficient arrangement for pumping out all bilge water from a vessel having a double bottom tank.
See p. 205 *and fig.* 160.

Question 68.—Describe an ordinary hand pump. What should b the maximum height of the suction chamber above the water-level, and why?
See p. 202, *and sketch fig.* 157A.

Question 69.—What precautions should be taken in filling water-ballast tanks?
See p. 206.

Question 70.—What is a gudgeon?
See p. 176, *and fig.* 132. *Illustrate by sketch, fig.* 135.

Question 71.—What is a rudder pintle?
See pp. 176, 186. *Illustrate by sketch, fig.* 133.

Question 72.—Show a good method of gudgeon fitting so as to easily repair wear and tear.
See pp. 185–7, *and figs.* 133, 134, 136, 137. *Illustrate by sketching one method or more.*

Question 73.—What method is adopted to prevent the rudder unshipping at sea?
See p. 187, *and figs.* 136 *and* 145. *Illustrate by sketching the former.*

Question 74.—What are rudder stoppers?
See p. 187 *and figs.* 138 *and* 145. *Illustrate by sketching the former.*

Question 75.—Show a good method of readily unshipping a rudder.
See p. 185, *and fig.* 146. *Illustrate by sketching the coupling in fig.* 146.

Question 76.—Describe how the stern frame is connected to the hull in a single-screw steamer.
See p. 175. *Read also answers to Ques.* 2, 3, and 4. *Illustrate by sketching from fig.* 132.

Question 77.—Illustrate by a sketch the riveting in a stern frame, giving size, arrangement, and spacing of rivets.
See p. 175, *and sketch from fig.* 132.

Question 78.—What is the advantage of making a stern frame in two pieces? Show a good arrangement of scarphs—and one of the latter in detail.
See p. 173, *and fig.* 132.

Question 79.—What is the best method of supporting the after shafting and propeller of a large twin-screw steamer? What are the spectacles?
See p. 179, *and figs.* 143, 144.

Question 80.—What is a plate rudder, and what a frame rudder? Show how each is constructed.
See p. 185, *and figs.* 145 *and* 146.

Question 81.—Enumerate the tests for steel castings.
See p. 187.

Question 82.—Sketch a good arrangement of keel blocks and launching ways.
See figs. 83, 26.

Question 83.—What is meant by declivity of keel blocks, declivity of launching ways, and camber of ways? Give usual allowance in each case.
See pp. 57, 58, 64, 118, 120, 207–9, *and figs.* 83 *and* 162.

Question 84.—What considerations influence the fixing of the keel slope, the declivity of the launching ways, and the height of the foremost block (assuming vessel launched stern first)?
See pp. 119–20, 57, 58.

Question 85.—Why is camber given to the launching ways?
See pp. 209–11, 58.

Question 86.—At what point in a vessel's travel down the ways does the after body become water-borne?
See p. 209.

Question 87.—What considerations affect the determination of the after termination of the launching ways?
See p. 58.

Question 88.—Explain the term "tipping moment." Illustrate by means of a sketch its importance in the operation of launching.
See pp. 58, 120, 208–11, *and fig.* 163.

Question 89.—Mention a satisfactory lubricant for launching ways.
See p. 61.

Question 90.—Explain the term "launching cradle," and show why the fore cradle should be specially strong.
See pp. 58–61, 209–11, *and figs.* 29, 30, 163B.

INDEX.

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